# City of Avalon

## Santa Catalina Island

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CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD LOS ANGELES REGION

November 30, 2012

**VIA ELECTRONIC & U.S. MAIL**

Samuel Unger
Executive Officer
California Regional Water Quality Control Board
Los Angeles Region
320 West 4th Street, Suite 200
Los Angeles, CA 90013-2343

Re: Avalon Bay Fecal Indicator Bacteria Wasteload Allocation Compliance Plan

Dear Mr. Unger:

In accordance with paragraph 28 of the Regional Board's Cease and Desist Order No. R4-2012-0077 ("CDO"), the City of Avalon submits the enclosed Avalon Bay Fecal Indicator Bacteria Wasteload Allocation Compliance Plan ("Compliance Plan") for the Executive Officer's approval. As required by the CDO, the Compliance Plan includes implementation methods, and proposed milestones (i.e., actions and dates) to track progress toward achieving the WLAs of the FIB TMDL. Although paragraph 29 of the CDO provides that the City must implement the approved Compliance Plan within 90 days of the Executive Officer's approval, the City intends to move forward with the Compliance Plan immediately. If corrections to the Compliance Plan are required by the Executive Officer, the City will address those corrections within the 90 days provided in paragraph 29 of the CDO.

The City is committed to achieving the requirements of the CDO and seeking to achieve the WLAs of the FIB TMDL as set forth in the Compliance Plan. The City has invested significant money and time in improving its collection system infrastructure and its POTW, and, through the Compliance Plan, believes that it has set forth a process for seeking to achieve the WLAs of the TMDL. The City thanks the Regional Board for its consideration of the Compliance Plan and looks forward to its approval.

Sincerely,

Charles Wagner
Chief Administrative Officer
City of Avalon

Enclosure

cc: Shawn Hagerty, Esq.


| *Administration/ Public Works* | *Finance* | *Harbor Department* | *Fire Department* | *Recreation Department* | *Planning/Building Capital Improvements* |
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# AVALON BAY FECAL INDICATOR BACTERIA WASTELOAD ALLOCATION COMPLIANCE PLAN

**Submitted To:** **The Los Angeles Regional Water Quality Control Board**

**Submitted By:** **The City of Avalon**

**NOVEMBER 30, 2012**

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## SECTION 1. BACKGROUND AND PURPOSE

The purpose of this Avalon Bay Fecal Indicator Bacteria Wasteload Allocation Compliance Plan ("Compliance Plan") is to establish the measures that the City of Avalon ("Avalon" or the "City") intends to take to satisfy the wasteload allocations ("WLAs") set forth in the Total Maximum Daily Load for Fecal Indicator Bacteria for Avalon Bay (the "FIB TMDL"). The Compliance Plan describes the factual and legal background of the FIB TMDL, assesses the sources of fecal indicator bacteria at Avalon Bay, describes a range of load reduction options, establishes an implementation plan and sets forth milestones for achieving the WLAs.

This Section 1 of the Compliance Plan provides the factual and legal background for the FIB TMDL.

### A. Description of the City and the Avalon Bay Watershed.

Avalon is located on Santa Catalina Island, in the County of Los Angeles, approximately 22 miles south-by-southwest of the Los Angeles Harbor breakwater. The City is located in a valley and fronts on the Pacific Ocean at Avalon Bay. Approximately half of the residential structures and the City's entire commercial district have been developed on the flat area facing Avalon Bay. The remaining residences are on terraced streets rising into the surrounding hills.

The City is oriented around Avalon Bay and its harbor. Crescent Avenue, along which many of the visitor-serving commercial businesses are located, runs in a crescent shape behind the beach at Avalon Bay. Extending out into the center of the harbor is the Green Pleasure Pier.

Avalon Bay is an active recreational boating harbor containing several hundred moorings and related facilities. Avalon Bay is a no-discharge area, and the City's harbor patrol officials operate a dye tab program to verify that boats within the harbor are not discharging to the Bay.

Avalon Bay is located on the southeast side of Catalina Island (area 200 $km^2$), at approximately 33°20.9' N, 118°19.5' W (Figure A). The site has a Mediterranean climate typical of coastal southern California, with warm (17 to 28°C) dry summers and cool (9 to 18°C) wet winters; an average of 1 to 3 inches of rain falls in a typical month in the wet season, from November through March.[1] The Bay experiences 3 to 6 feet mixed-tides that vary in amplitude with the spring-neap cycle. Beaches within the Bay are sheltered from large waves present on the open coast, and are characterized by a ratio of tide range to wave height typically >3. Two breakwaters flank the entrance to Avalon Bay (Figure B). The Cabrillo Mole (or "Mole"), located at the south end of the harbor, serves as the main dock for cross-channel passenger boats. At the north end of the harbor is the Catalina Casino breakwater. Despite the presence of these breakwaters, there is vigorous tidal exchange of water between the Bay and the Ocean, and significant within-Bay turbulent mixing and advective transport.[2]

The City is the largest town (area 6.9 $km^2$) on the island with 3,500 year-round residents, and its primary source of revenue is tourism. On a typical summer day 17,500 tourists arrive via ferry, cruise ship, or personal vessel, and up to 400 vessels are moored in Avalon Bay.

The City owns and operates (through a contract with Environ Strategy Consultants, Inc) a publicly owned treatment works ("POTW") and related collection system to serve the City's wastewater needs. The POTW is located at 123 Pebbly Beach Road, southwest of the developed portions of the City and the Bay. The POTW treats municipal wastewater, which is a mixture of fresh and salt water, from domestic and commercial sources. The POTW has an average dry weather design treatment capacity of 1.2 million gallons per day (mgd). The treated wastewater is discharged 400 feet offshore into the Pacific Ocean at a depth of 130 feet, in accordance with a National Pollutant Discharge Elimination System ("NPDES") permit R4-2008-0028; NPDES No. CA0054372), through an outfall located off Pebbly Beach Road, at approximately the half-way point between the POTW and Avalon Bay (3°20.19' N, 118°18.40' W).

The collection system for the POTW consists of 7.1 miles of gravity pipes ranging from 6-inch to 15-inch in diameter, as well as 1.2 miles of 16-inch and 12-inch diameter force mains. Major portions of the collection system are located in Crescent Avenue, adjacent to the Bay. There are two sewer lift stations, the Catherine lift station and the Pebbly Beach lift station. The collection system has recently undergone significant rehabilitation and replacement.

The City also owns and operates a municipal separate storm sewer system ("MS4"). The MS4 consists of two main components:

(1) A flood control channel that drains Avalon Canyon.

(2) A network of street drains, roof drains, and subsurface pipes that collectively drain the developed areas of the City.

The flood control channel, known as Clarissa Channel, discharges to the southwest corner of Avalon Bay. The downtown drainage is divided into seven sub-drainages that discharge through storm drains distributed around the perimeter of the Bay. To divert dry-weather flows and the "first flush" of rain events to the POTW, the City has installed a series of low flow interceptors at the Clarissa Channel and the Crescent Avenue storm inlets.

The main beach area of Avalon Bay has suffered chronic water quality problems, with fecal indicator bacteria ("FIB") concentrations frequently exceeding State and Federal guidance criteria for marine bathing waters. Furthermore, water testing along the shoreline has revealed the presence of several indicators of human waste, including human fecal-specific *Bacteroidales* and human enterovirus.[3] [4] A series of studies have implicated sewage contaminated shallow groundwater as a potential source of FIB in the nearshore region, which appears to enter the Bay from the shoreline during falling tides.[5] [6] In response to these studies, the City has just completed a comprehensive sewage collection system upgrade and replacement project. This project is designed to correct leaks and historic deficiencies in the collection system. The project was completed this year and it is believed that leaks from the collection system have been stopped. As more fully described in this Compliance Plan, the City will implement programs to address potential leaks from laterals leading to the collection system, which appear to require corrections.

**Figure A.**

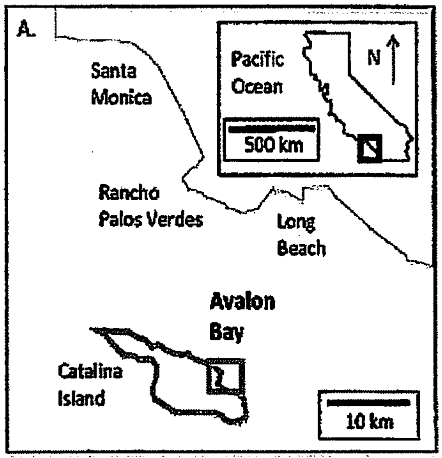
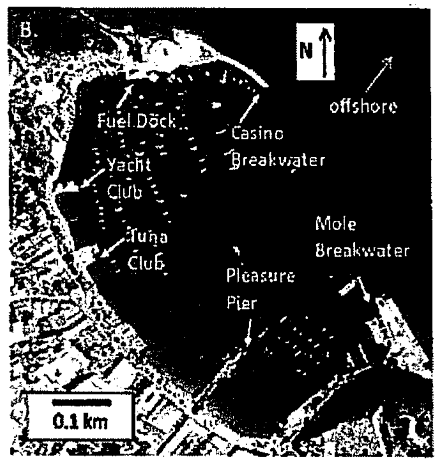



**Figure B.**




The Water Quality Control Plan for the Coastal Watersheds of Los Angeles and Ventura Counties ("Basin Plan") designates a range of beneficial uses for Santa Catalina Island, including, as relevant to Avalon Bay, Water Contact Recreation (REC-1) and Non-Contact Water Recreation (REC-2). In or about 1999, the County of Los Angeles began testing Avalon Bay for FIB at 5 monitoring locations during the summer season (April 1 – October 31) in accordance with Health and Safety Code section 115880, also known as AB 411. Despite a variety of City programs and capital improvements designed to address the bacteria problem, the AB 411 test results at the 5 monitoring locations frequently exceed the minimum bacteriological standards for public beaches. As a result, beaches in Avalon have been posted as unsuitable for water contact recreation. For these reasons, Avalon Bay is listed on the 2008/2010 Clean Water Act section 303(d) impaired waters list as impaired due to indicator bacteria.

B. <u>FIB TMDL Requirements</u>.

In April of 2012, in connection with Cease and Desist Order No. R4-2012-0077 (the "CDO"), the Los Angeles Regional Water Quality Control Board ("Regional Board") adopted the FIB TMDL. Under the federal Clean Water Act ("CWA"), a Total Maximum Daily Load ("TMDL") is a calculation of the maximum amount of a pollutant that a water body can receive and still meet the water quality standards established for that water body. A TMDL establishes this maximum pollutant "load" and then allocates that "load" among the various sources of the pollutant. Point sources receive a wasteload allocation and non-point sources receive a load allocation. Through an implementation plan, these sources of the pollutant must reduce their "loading" of the pollutant to achieve the requirements of the TMDL over a fixed period of time.

The FIB TMDL is based upon bacteriological water quality objectives for marine water to protect the water contact recreational beneficial uses. The FIB TMDL therefore establishes the following numeric targets for Avalon Bay:

<u>Geometric Mean Limits</u>

Total coliform density shall not exceed 1,000/100 ml.
Fecal coliform density shall not exceed 200/100 ml.

Enterococcus density shall not exceed 35/100 ml.

Single Sample Limits

Total coliform density shall not exceed 10,000/100 ml.
Fecal coliform density shall not exceed 400/100 ml.
Enterococcus density shall not exceed 104/100 ml.
Total coliform density shall not exceed 1,000/100 ml, if the ratio of fecal-total coliform exceeds 0.1.

Using a "reference system/anti-degradation approach," the FIB TMDL then translates these numeric limits into wasteload allocations based upon the number of exceedance days that may occur and still maintain the beneficial use. As the sole point-source discharger who is subject to the TMDL, Avalon receives the entire WLA, to be achieved as follows:

- No exceedances of the numeric targets for discharges from the City's POTW.
- By June 30, 2015, there shall be no discharge from the City's sanitary sewer collection system resulting in detectable levels of the fecal indicator bacterial identified as numeric targets in the FIB TMDL.
- By April 1, 2016, there shall be no allowable exceedances at any locations during summer dry weather (April 1 to October 31).
- By November 1, 2016, compliance with the allowable number of winter dry-weather exceedance days shall be achieved (November 1 to March 31). If daily sampling occurs, the allowable number of winter dry-weather exceedance days is 9 for each monitoring site. If weekly sampling is conducted, 1 allowable winter dry-weather exceedance day is provided.
- By November 1, 2017, compliance with the allowable number of wet-weather exceedance days and geometric mean targets must be achieved. If daily sampling occurs, the allowable exceedance days for wet-weather is 17. If weekly sampling is conducted, the allowable exceedance days for wet-weather is 3.

C. Plan Objectives.

In accordance with paragraph 28 of the CDO, Avalon must submit a report by November 30, 2012 to the Executive Officer of the Regional Board, describing how Avalon intends to comply with the above-described WLAs. The CDO provides that the report must include implementation methods and proposed milestones (i.e., actions and dates) to track progress toward achieving the WLAs by the dates established in the FIB TMDL (as summarized above).

This Compliance Plan is submitted to the Regional Board to satisfy the requirements of paragraph 28 of the CDO. The objective of the Compliance Plan is to identify nonstructural and structural best management practices ("BMPs") that will assist the City in achieving the WLAs, and to establish a schedule by which the City will implement those BMPs. The milestones established in this Compliance Plan will track the City's progress toward achieving the WLAs by the dates established in the TMDL.

The Compliance Plan is based on a large body of existing and new scientific studies related to Avalon Bay. Previous studies relied upon in the Compliance Plan include reports based on scientific studies of Avalon Bay funded by the City and by the State of California Clean Beaches Initiative,[7] [8] [9] [10] research articles published from those studies,[11] [12] [13] [14] research articles published by other reputable scientists who have studied the water quality problem in Avalon Bay,[15] [16] and relevant reports.[17]

In addition, the Compliance Plan is based on two recent studies performed by Stanley B. Grant, Ph.D., and called for in paragraphs 34 and 35 of the CDO. These two studies address bacterial loading from anthropogenic and non-anthropogenic sources and bacterial residence times in shallow groundwater beneath the City.

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[1] WRCC, W. R. C. C. http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?caaval+sca

[2] Bogucki, D. J.; Jones, B. H.; Carr, M. E., Remote measurements of horizontal eddy diffusivity. Journal of Atmospheric and Oceanic Technology 2005, 22, (9), 1373-1380.

[3] Boehm, A. B. Y., K.M.; Love, D.C.; Peterson, B.M.; McNeill, K.; Nelson, K.L., Covariation and Photoinactivation of Traditional and Novel Indicator Organisms and Human Viruses at a Sewage-Impacted Marine Beach. Environmental Science & Technology 2009, 43, (21), 8046-8052.

[4] Boehm, A. B. F., J.A.; Mrse, R.D.; Grant, S.B. , Tiered approach for identification of a human fecal pollution source at a recreational beach: Case study at Avalon Bay, Catalina Island, California. Environmental Science & Technology 2003, *37*, (4), 673-680.

[5] *See* Boehm, A. B. Y., K.M.; Love, D.C.; Peterson, B.M.; McNeill, K.; Nelson, K.L., Covariation and Photoinactivation of Traditional and Novel Indicator Organisms and Human Viruses at a Sewage-Impacted Marine Beach. Environmental Science & Technology 2009, 43, (21), 8046-8052.

[6] *See* Boehm, A. B. F., J.A.; Mrse, R.D.; Grant, S.B. , Tiered approach for identification of a human fecal pollution source at a recreational beach: Case study at Avalon Bay, Catalina Island, California. Environmental Science & Technology 2003, *37*, (4), 673-680.

[7] Grant, S.B., R. Mrse, C. Jensen-McMullin, M. Bachman, A. Boehm, J. Fuhrman, B. Jones "Sources and mitigation of water quality impairment in Avalon Bay, Catalina Island, California" Report submitted to the City of Avalon and the State Water Resources Control Board Clean Beaches Initiative (March 27, 2006).

[8] Grant, S.B., R. Litton, L. Ho, M. Bailey, J. Monroe, S. Wuertz, L. Liu, "Avalon Bay Water Quality Improvement Project, Catalina Island, California: A final report on Shallow Groundwater Characterization, Task B.1 of the Clean Beaches Initiative Grant", submitted to the City of Avalon and the State Water Resources Control Board (August 24, 2010).

[9] Grant, S.B., R. Litton, L. Ho, M. Bailey, J. Monroe, S. Wuertz, L. Liu, "Avalon Bay Water Quality Improvement Project, Catalina Island, California: A final report on Pilot Disinfection Studies, Task B.2 of the Clean Beaches Initiative Grant", submitted to the City of Avalon and the State Water Resources Control Board (August 24, 2010).

[10] Grant, S.B., R. Litton, L. Ho, M. Bailey, J. Monroe, M. Bailey, "Avalon Bay Water Quality Improvement Project, Catalina Island, California: A final report on Source Identification of FIB in Ankle Depth Waters in Avalon Bay, Task B.3 of the Clean Beaches Initiative Grant", submitted to the City of Avalon and the State Water Resources Control Board (August 24, 2010).

[11] Bogucki, D. J.; Jones, B. H.; Carr, M. E., Remote measurements of horizontal eddy diffusivity. Journal of Atmospheric and Oceanic Technology 2005, 22, (9), 1373-1380.

[12] Boehm, A. B. F., J.A.; Mrse, R.D.; Grant, S.B. , Tiered approach for identification of a human fecal pollution source at a recreational beach: Case study at Avalon Bay, Catalina Island, California. Environmental Science & Technology 2003, *37*, (4), 673-680

[13] Ho, L.C., R.M. Litton, S.B. Grant, "Anthropogenic Currents and Shoreline Water Quality in Avalon Bay, California", Environmental Science & Technology 2011, 45, 2079-2085.
[14] Bailey, M.M., W. J. Cooper, S.B. Grant "In situ disinfection of sewage contaminated shallow groundwater: A feasibility study" Water Research 2011, 45, 5641-5653.
[15] Boehm, A. B. Y., K.M.; Love, D.C.; Peterson, B.M.; McNeill, K.; Nelson, K.L., Covariation and Photoinactivation of Traditional and Novel Indicator Organisms and Human Viruses at a Sewage-Impacted Marine Beach. Environmental Science & Technology 2009, 43, (21), 8046-8052.
[16] Maraccini, P.A., D.M. Ferguson, A.B. Boehm "Diurnal Variation in Enterococcus species composition in polluted ocean water and a potential role for the Enterococcal Cartenoid in protection against photoinactivation", Applied and Environmental Microbiology, 2012, 78(2), 305-310.
[17] Hamilton, P., "Avalon Canyon Ground Water Investigation, Santa Catalina Island", a report prepared for the Santa Catalina Island Company (SCIC) (October 18, 1999).

## SECTION 2. SOURCE ASSESSMENT AND LOAD REDUCTION OPTIONS

Avalon Bay has been the subject of significant technical study over the past decade. These studies have focused on various potential sources of the bacteria in Avalon Bay. During the summer of 2012, consistent with paragraphs 34 and 35 of the CDO, the City retained Dr. Stanley Grant to perform additional studies of the potential bacteria sources at Avalon Bay. This Section 2 of the Compliance Plan summarizes the existing science concerning the sources of FIB in Avalon Bay and discusses load reduction options available to the City. These load reduction options and how the City might implement them are then described in more detail in Section 3 of the Compliance Plan.

A. Summary of Previous Scientific Studies.

In 2001, Avalon received a $500,000 grant from the State of California's Clean Beaches Initiative ("CBI") to investigate the water quality problem in Avalon Bay. The study portion of the grant was carried out between September and November 2001, and was led by Professors Stanley Grant (UCI), Burt Jones (USC), and Jed Fuhrman (USC). The study had three goals:

(1) Identify the physical location of FIB impairment in Avalon Bay.

(2) Conduct microbial source tracking studies to identify potential sources of FIB in Avalon Bay.

(3) Characterize circulation in Avalon Bay.

The CBI study concluded the following:[1]

(a) Within Avalon Bay, FIB concentrations are highest in ankle depth water along the shoreline. FIB concentrations in the water and sediment are generally below detectable levels a very short distance (<10 m) bayward of the shoreline. The source of FIB appears to be located at or near the shoreline in Avalon Bay. Partially treated sewage discharged from the POTW does not appear to be a significant source of FIB in Avalon Bay.

(b) Several land-side sources of FIB were identified, including bird and animal fecal droppings, broken plumbing under wharf structures, run-off from street wash down activities, and contaminated shallow groundwater. Microbial indicators of human fecal pollution (including the human-specific bacteria *Bacteroides/Provetella* and human enterovirus) were detected at several locations in Avalon Bay, and in groundwater sampling pits, suggesting that human sewage from leaking sewage collection lines and laterals may contribute to water quality impairment of Avalon Bay.

(c) A significant fraction of the water in Avalon Bay is exchanged with the Ocean over a single tide cycle. Mixing in the Bay is sufficient to quickly disperse contaminants introduced to the Bay, provided that the source of contamination is not continuous. The region of the Bay impacted by the storm drain (near the beach site called "Channel") does not appear to have a circulation problem. Within one hour, pollutants released into this area of the Bay are transported 200 to 300 feet into the Bay and diluted by a factor of 100 or more.

In 2009, the City received a $1.35 million grant from the State of California's Clean Beaches Initiative for sewer inspection and repair, and to conduct follow-up water quality studies led by Professors Stanley Grant (UCI), Stefan Wuertz (UCD), and Lanbo Liu (U. Connecticut). The water quality studies were designed to:

(1) Characterize the extent of the sewage-contaminated shallow groundwater beneath the City.

(2) Carry out a bench-scale pilot remediation study of sewage contaminated shallow groundwater.

(3) Identify sources of FIB in ankle-depth waters.

The study concluded the following:[2 3 4]

(a) During falling tides, brackish shallow groundwater below the City is discharged to Avalon Bay near the Pleasure Pier, at Busy Bee Wharf, and at Step Beach. Shallow groundwater sampled from wells installed near Step Beach, and in front of the Busy Bee Wharf, had a number of characteristics consistent with sewage contamination.

(b) The groundwater beneath the City is brackish, and thus pilot studies were needed to identify the best approach for the in situ disinfection of sewage-contaminated groundwater. Of the different methods evaluated, the most promising approach appears to involve the use of the chemical disinfectant peracetic acid (PAA), which could be applied directly to sewage contaminated sediments, or injected into areas where sewage leaks are known or presumed to have contaminated the subsurface. Pump and treat methods and permeable treatment barriers are less promising, because of unresolved difficulties associated with mobilizing sewage-associated bacteria and pathogens out of sewage contaminated sediments, and proper placement of in situ filter media given the highly variable nature of sewage contamination of the shallow groundwater.

(c) Surficial beach sand appears to be contaminated with sewage-associated markers at several locations around the perimeter of Avalon Bay, including Pleasure Pier, Busy Bee, and Step Beach. Furthermore, evidence is presented that at a few locations around Avalon Bay the seepage face—which forms when water level in the Bay drops below the shallow groundwater table—is contaminated with markers of sewage.

B. Summary of 2012 Bacterial Loading Studies.

Avalon has taken a number of steps over the years to reduce the loading of FIB to Avalon Bay including:

(1) Extensive repairs of the sewage collection system, including the expenditure of $5.7 million on sewer line repairs in the past year alone.

(2) Strict control of black water (e.g., from toilets) discharges to the Bay from pleasure craft, including mandatory dye tabbing of boat heads, and the one-year expulsion of boaters caught discharging to the Bay.

(3) Bird control efforts, including the stringing of fishing line near the shoreline.

(4) Installation of low-flow interceptors to divert dry weather runoff to the sanitary sewer system.

(5) Modification of street wash-down procedures to reduce the flow of nuisance runoff to the beach.

(6) Repair of plumbing under docks and wharfs around the perimeter of Avalon Bay.

To date, these activities alone have not completely addressed shoreline water quality in Avalon Bay, and thus additional efforts are proposed as part of this Compliance Plan. To assist the City in the development of strategies to address the problem, paragraph 34 of the CDO requires the City to conduct a study of bacterial loading to Avalon Bay from anthropogenic and non-anthropogenic sources, including "but not limited to storm drains, boats, birds, the pier, and other sources." This Section 2.B of the Compliance Plan summarizes the studies the City carried out during the summer of 2012 to satisfy this requirement.

1. **Anthropogenic Sources.**

(a) Bay Side Plumbing and Other Laterals.

The FIB TMDL establishes separate WLAs for the different potential sources of the bacteria (i.e., POTW or MS4/non-point sources) and for different combinations of seasons and rainfall (i.e., summertime dry-weather versus wintertime dry-weather versus wet-weather). Considerable effort and money are being devoted to improving POTW operations and the collection system, and it is anticipated that the WLAs for the POTW and the collection system will be achieved through those efforts. However, there is a risk that certain laterals that connect to the collection system, particularly sewer laterals and plumbing near the beach (collectively referred to here as "Bay Side Plumbing"), may continue to contaminate the shallow groundwater and cause water quality exceedances in Avalon Bay.

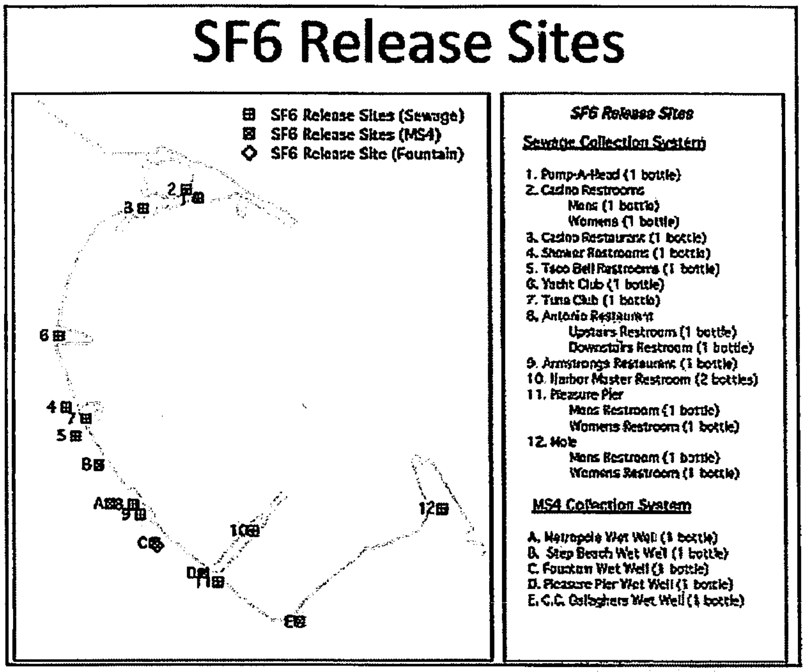
To assess the degree to which Bay Side Plumbing may contribute to the water quality problem in Avalon Bay, the artificial tracer sulfur hexafluoride ("$SF_6$") was injected into selected toilets, sewer manholes, dry-weather diversion structures, and shower drains located within 300 feet of the beach, and monitored over time in the shoreline waters of

Avalon Bay. $SF_6$ is a non-toxic and non-reactive gas, and an ideal tracer of groundwater flow. Its movement through groundwater is not retarded in porous media,[5] and it has been used for decades as a tracer for mixing and gas exchange in a number of settings, including lakes, rivers, and the open ocean. It has been used successfully in groundwater studies in California (Orange, Los Angeles and Ventura Counties) that traced the movement of artificially recharged water through groundwater systems.[6 7]

There are a number of advantages of using $SF_6$ as a tracer in the subsurface. First, $SF_6$ is more economical than most other tracers and, hence, more water can be tagged, decreasing the probability that the tracers will pass undetected. Second, it does not change the density of the tagged water, thus buoyancy effects do not complicate the interpretation of the experimental results. Third, $SF_6$ does not degrade the quality of the water, and at the concentrations utilized for groundwater the tracer causes no known adverse health effects. Fourth, because it is a gas, $SF_6$ can be removed from water easily by aeration, and detected by sensitive techniques, such gas chromatography.

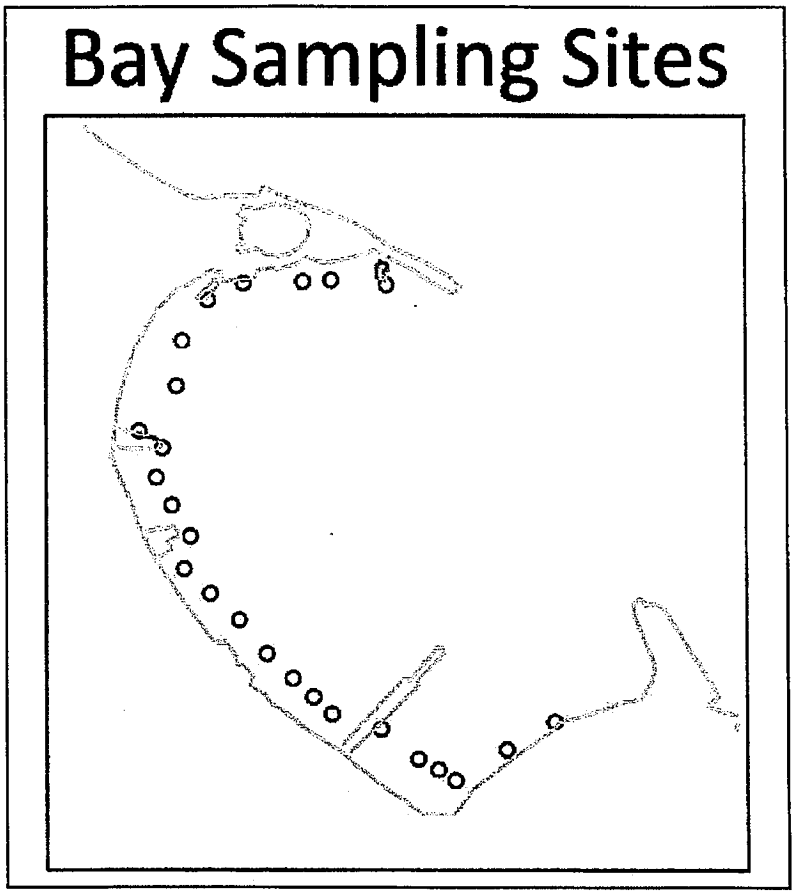
The $SF_6$ study was conducted as follows. Twenty-two bottles containing approximately 1 liter of $SF_6$-charged rainwater were prepared by Dr. Jordan Clark at the University of California, Santa Barbara and then transported by hand to the Avalon field site on September 13, 2012. On September 13 at approximately 20:00 (8:00 PM) PST, $SF_6$-charged water was added to a total of 17 sites that drain to the City's sewage collection system, including 12 sewer sites and 5 dry weather diversion sites (Figure C). The sewer sites included toilets and sewer lines near the beach; the latter were accessed through sewer manholes. The diversion sites were underground dry weather diversion structures near the main beach (accessed through storm sewer manholes). Weather during the study was warm and dry, and field observations indicated the dry weather diversion structures were functioning properly; i.e., nuisance runoff was not entering Avalon Bay through the MS4 outlets. Thus, $SF_6$ added to the dry weather diversion structures should have flowed directly into the sewage collection system. The 17 $SF_6$ release sites were selected based on consensus discussions with City staff and water quality scientists involved in the study, and collectively represented a comprehensive test of Bay Side Plumbing in the City.

**Figure C.**



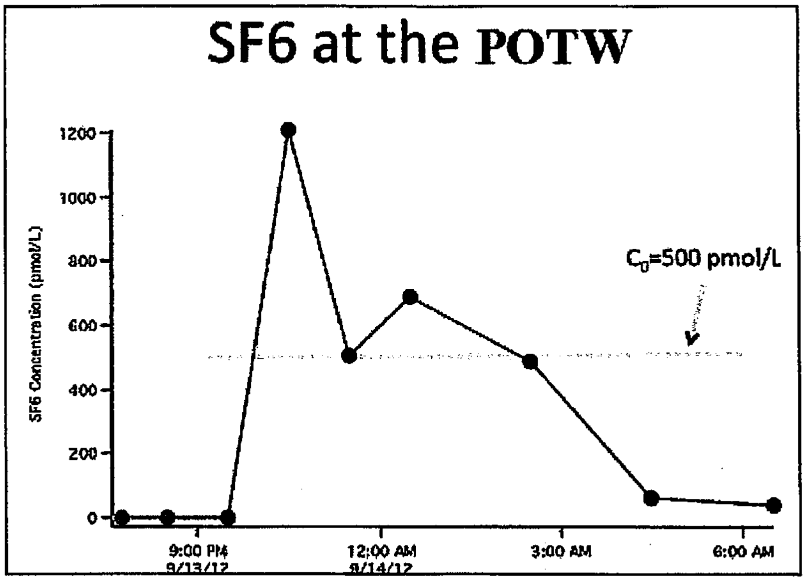

Following the addition of $SF_6$, water samples were collected twice daily (once in the morning and again in the evening) at approximately 25 sites distributed around the perimeter of Avalon Bay (Figure D). These two sampling times followed the high-low tide (morning sampling event) and low-low tide (evening sampling event). The first sampling event commenced at 21:00 on September 13, approximately 1 hour after $SF_6$ was added to the Bay Side Plumbing. Twice-daily sampling continued until the evening of September 17; a final sampling event was carried out twenty-four hours later, on the evening of September 18. Water samples were also collected from the influent of the City's sewage treatment plant. These sewage influent samples, which were collected to obtain a rough estimate of the concentration of $SF_6$ in the sewage collection system, were collected approximately hourly for the first 12 hours following addition of the $SF_6$. Water samples from Avalon Bay and sewage influent were collected into vacuum sealed containers, and shipped to UC Santa Barbara where they were analyzed $SF_6$ by gas chromatography.

**Figure D.**



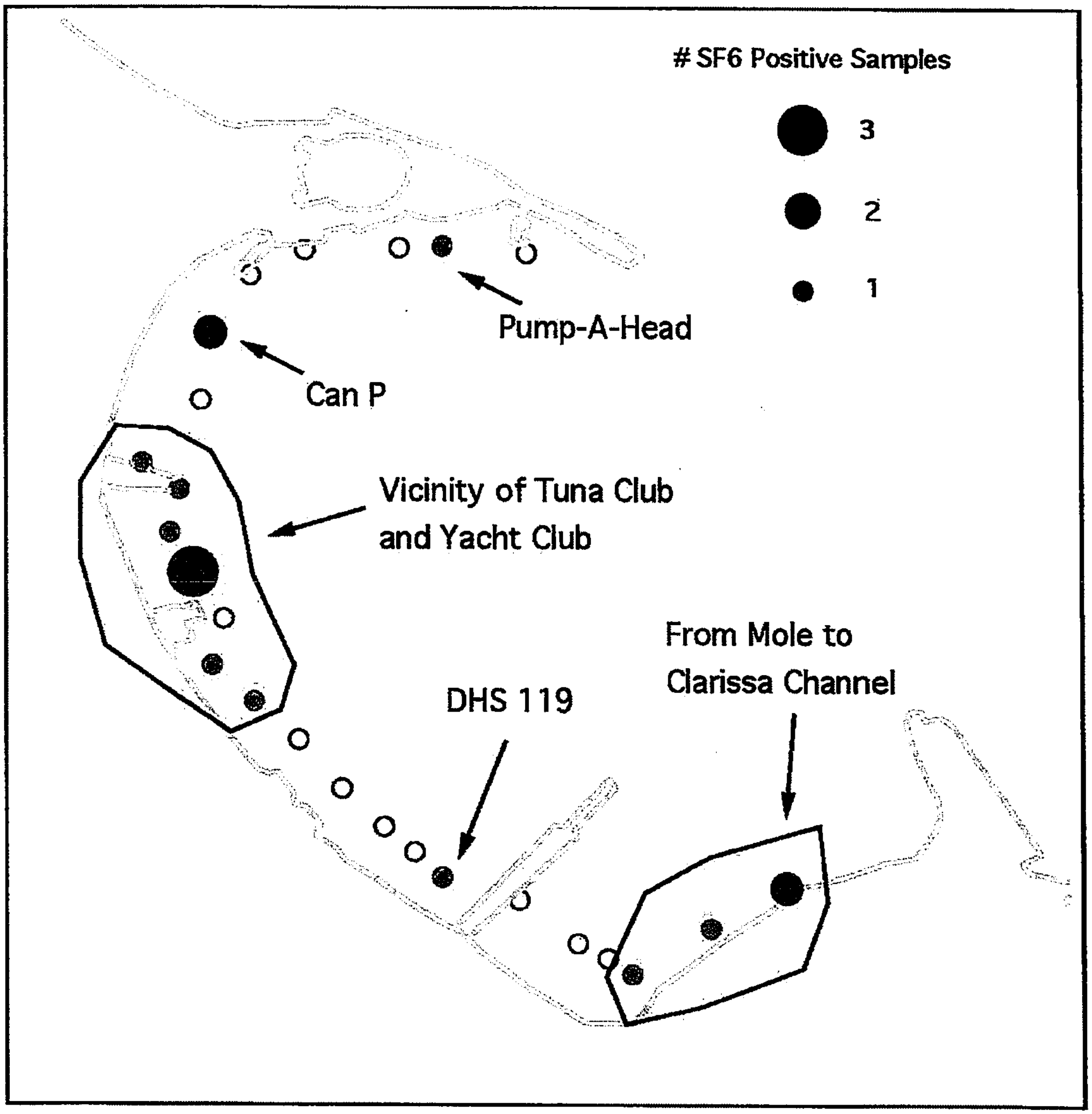

The concentration of $SF_6$ in the influent of the City's POTW was below the detection limit for approximately 1.5 hours following the release of the tracer, peaked 1 hour hour later, and steadily declined over the following eight hours (Figure E). Based on this result, most $SF_6$ traveled relatively quickly (~ 2 to 8 hours) through the sewage collection system, despite the fact that the Catherine Lift Station, which pumps sewage from the City of Avalon to the sewage treatment plant, was turned off for the first hour following the $SF_6$ release (the lift station was deliberately turned off to give the $SF_6$ time to leak out of the Bay Side Plumbing and into the shallow groundwater, if such leaks exist). Based on the data presented in Figure E, $C_o$= 500 pmol/L is a crude estimate for the concentration of tracer in the sewage collection system within the first couple of hours following its release.

**Figure E.**




Of the 274 water samples collected from Avalon Bay, approximately 6% (or 16 samples) tested positive for $SF_6$. Although the location and timing of these $SF_6$ positive samples varied throughout the study, some patterns are evident. Altogether, ten samples were collected from each sampling site in the Bay. Roughly half of the Bay sampling sites (13 of 25) had no samples testing positive for $SF_6$. Nine sites had one sample testing positive for $SF_6$, two sites had two samples testing positive for $SF_6$, and one site (between the Tuna Club and Yacht Club) had three samples testing positive for $SF_6$. Most of the positive samples cluster into one of two groups, (Figure F). Eight $SF_6$ positive samples were collected from around the Tuna Club and the Yacht Club. Four $SF_6$ positive samples were collected between the Mole and Clarrisa Channel. The remaining $SF_6$ positive samples were collected at the Pump-A-Head facility (1 sample), Mooring Can P (2 samples), and Department of Health Services (DHS) sampling site 119 just north of the Pleasure Pier (1 sample).

**Figure F.**




To give a sense of the timing and concentration of $SF_6$ detected in Avalon Bay, maps were prepared for each sampling date and time (Figures G and H). In these maps, the $SF_6$ results are presented in terms of dilution $D$, which represents a crude estimate for how much dilution occurred as $SF_6$-labeled sewage leaked from the Bay Side Plumbing, mixed into the shallow groundwater, and then mixed into the Bay: $D = C_o/C = (500\ \text{pmol/L})/C$, where $C$ represents the concentration of $SF_6$ detected at any particular sampling site. In this context, the lower the dilution, the more serious the sewage leak.

The lowest dilution ($D$=150) was measured between the Mole and Clarrisa Channel. Notably, this $SF_6$ positive sample was collected approximately one hour after $SF_6$ was released, indicating a very rapid transfer of the $SF_6$ from Bay Side Plumbing to the Bay (see map in Figure G labeled "September 13, 2012 at 21:00"). Some samples collected between the Mole and Clarrisa Channel were positive thirty-six hours later (September 15 at 0600), with implied dilutions of between 590 and 5300 (Figure G). $SF_6$ showed up at sites around the Tuna Club and Yacht Club one-to-two days after the $SF_6$ was released, with implied dilutions of between 400 and 1200. (Figures G and H). Overall, these results suggest significant heterogeneity in the pathways and travel times associated with the transport of sewage from leaks in the Bay Side Plumbing to Avalon Bay. In some locations (e.g., between the Mole and Clarissa Channel), the sewage is transported to Avalon Bay in a matter of hours, and the resulting dilutions are very low (<200). In other locations (e.g., between the Yacht Club and the Tuna Club), the sewage is transported to Avalon Bay over the course of several days, and the dilutions are larger (>400). Overall, the $SF_6$ study results document that Bay Side Plumbing is a source of sewage in Avalon Bay.

**Figure G.**

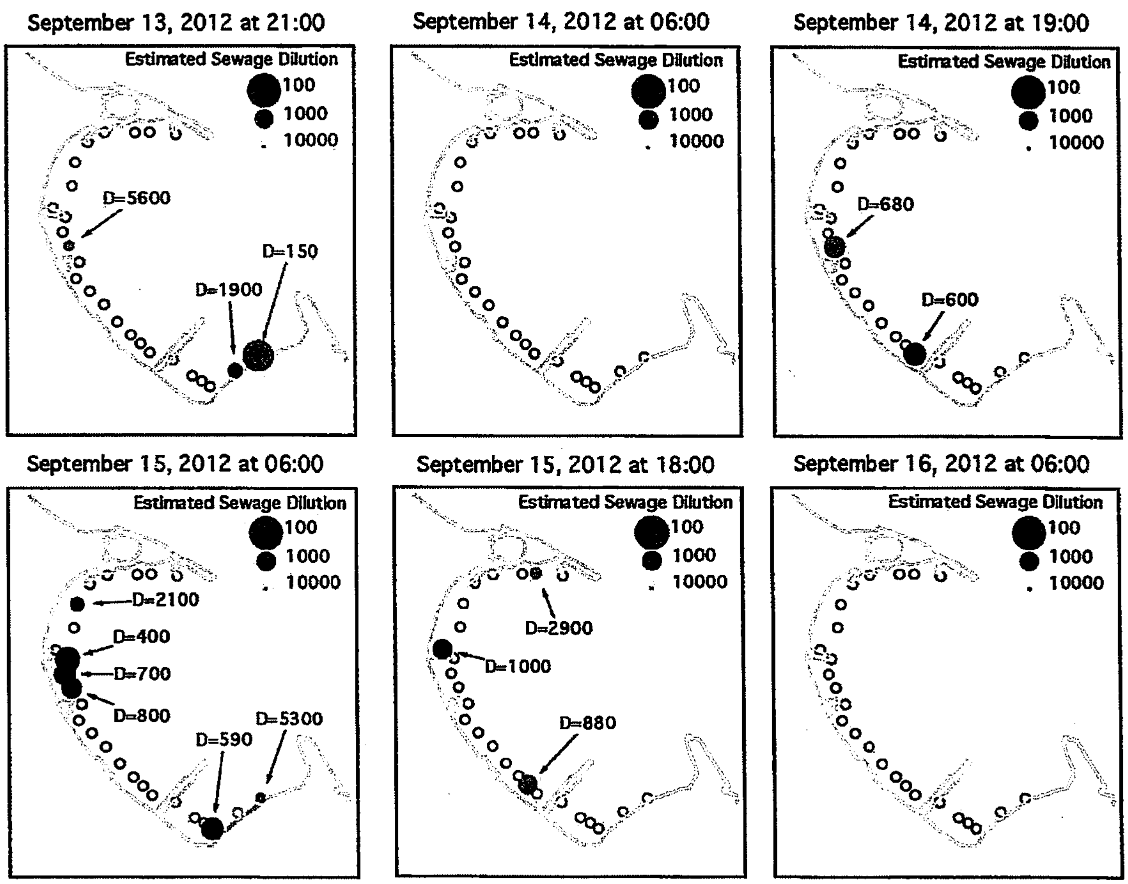
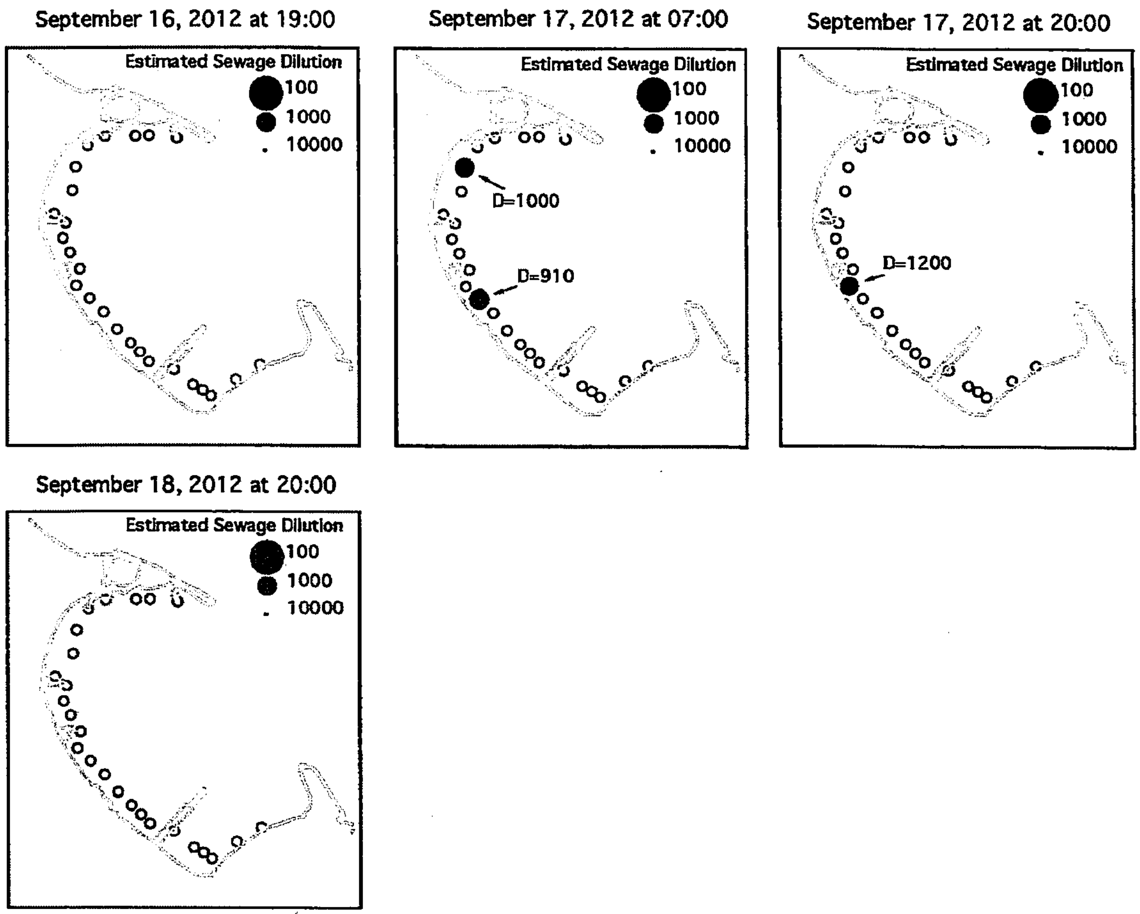


**Figure H.**

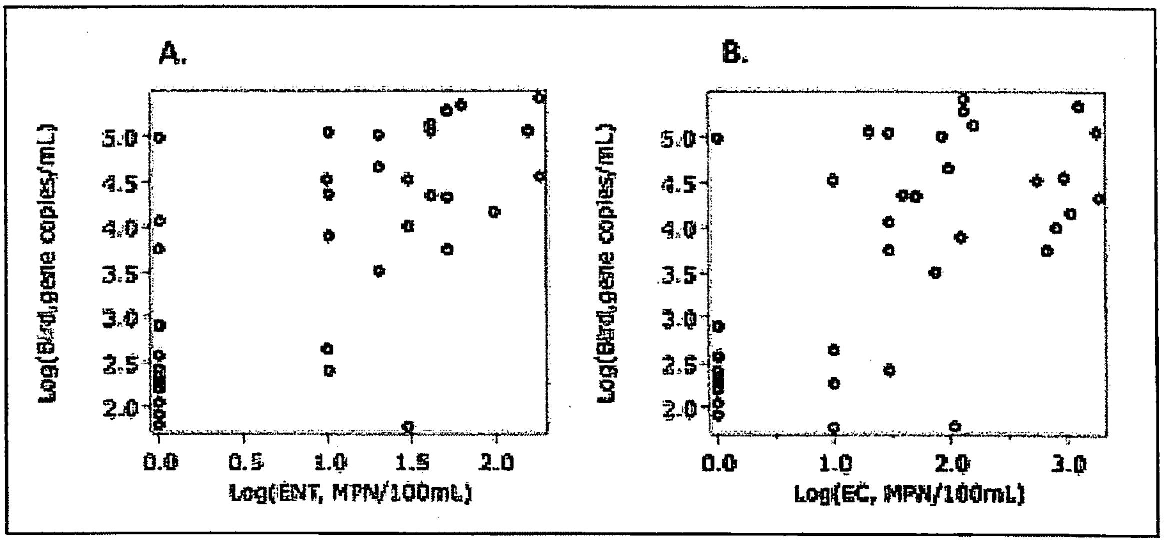



2. **Non-Anthropogenic Sources.**

(a) Bird Droppings.

The earlier 2000/2001 Clean Beaches Initiative study identified bird droppings as a potentially significant source of FIB in the nearshore waters of Avalon Bay.[8] Bird feces collected from various sites around the City, when suspended in Avalon Bay water, resulted in FIB concentrations that were hundreds of times the numeric targets established by the TMDL. Indeed, a follow-up Clean Beaches Initiative study, conducted in 2010, found that FIB concentrations along the shoreline in Avalon Bay are strongly correlated with a genetic marker for bird droppings (*Catellicoccus marimammalium*) (Figure I).

**Figure I.** *A cross-plot of a genetic marker for bird droppings (Catellicoccus marimammalium, vertical axis) against measurements of: (A) enterococci bacteria (ENT, horizontal axis), and (B) E. coli (EC, horizontal axis) in various water samples collected from Avalon Bay and groundwater (unpublished data). The bird marker, ENT, and EC concentrations are log (base 10) transformed.*



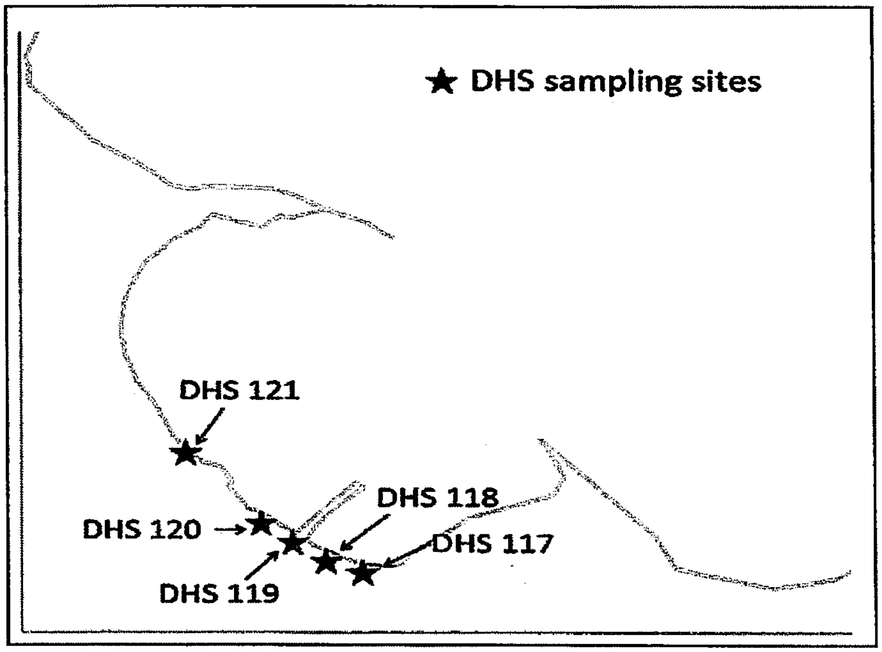

There are several different routes by which bird droppings could contaminate the nearshore waters of Avalon Bay. Bird droppings deposited on the beach during low tide can re-suspend and mix into nearshore waters during the next rising tide[9]. The practice of washing bird droppings off of boats, piers and floats is another potential source. Indeed, wash-down of the floats (e.g., at the Mole) typically occurs early in the morning, just before LA DHS personnel arrive on the ferry to collect water samples for their routine bathing water quality monitoring program. While the City of Avalon has a "zero tolerance" for boat head discharges to Avalon Bay, as noted above, wash-down of boats, piers, and floats still occurs. These wash-down activities transfer bird droppings into the Bay that may, in turn, adversely affect nearshore water quality.

In support of the development of this Compliance Plan, a ten-day wash-down moratorium was imposed on Avalon Bay, from September 10 to September 21, 2012. Several weeks before the start of the moratorium, businesses operating in and around Avalon Bay were sent a letter describing the moratorium on City stationary; in addition, a City official (Charlie Wagner) and study leader (Dr. Stanley Grant) spoke to a number of City residents and business owners about the need for the study, and answered their questions. During the first several days of the moratorium, Dr. Grant visited businesses located on the Mole and on the Pleasure Pier, to ask employees if they were aware of the wash-down moratorium, to answer any questions they might have about the moratorium, and to inquire how they were changing their clean-up practices while the moratorium was in effect. Generally speaking, community response to the moratorium was positive and proactive. Some businesses developed clever approaches for complying with the moratorium. Before the moratorium, Joe's Rent-A-Boat, which operates a skiff rental business on the Pleasure Pier, cleaned their floats by washing bird droppings into the Bay with a hose. During the moratorium, the owner directed his employees to hand scrub the floats with a bucket, eliminating the discharge of bird-dropping contaminated water into the Bay. There were also instances of moratorium violations, including a one-time decision by the Avalon

Harbor Master to wash down the Mole facility, out of concern that accumulated bird droppings on the floats and sidewalks posed a trip hazard to disembarking tourists.

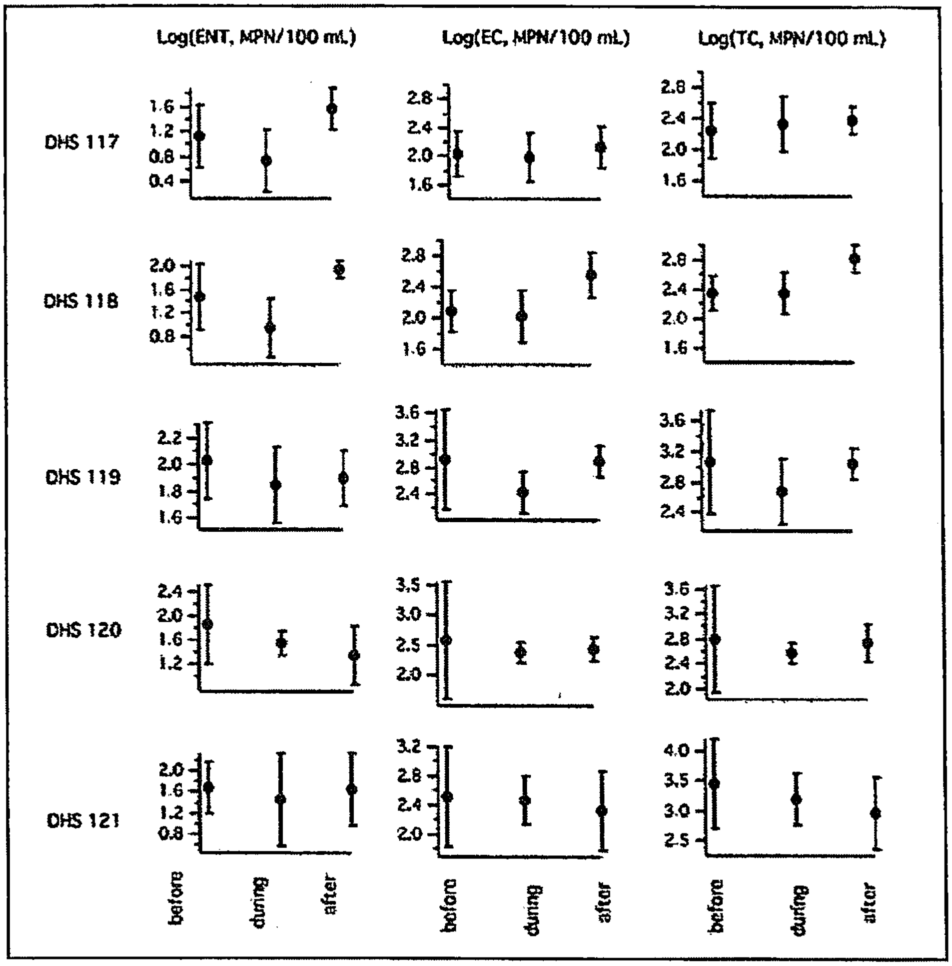
To assess the efficacy of the wash-down moratorium on Avalon Bay water quality, water samples were collected daily from the five LA Department of Health Services sampling sites (DHS 117 through 121, see Figure J) a week prior to the start of the moratorium, during the moratorium, and a week after the cessation of the moratorium. These water samples were analyzed for FIB (total coliform (TC), *E. coli* (EC), and enterococci (ENT)) using IDEXX Colilert 18 and Enterolert tests, following standard procedures. FIB measurements at each site were log-transformed, and means and standard deviations computed for all data collected before, during, and after the moratorium. The wash-down moratorium was judged to have improved water quality at a given site if TC, EC and/or ENT concentrations at the site were significantly lower during the moratorium, compared to before <u>and</u> after the moratorium.

**Figure J.** *Location of LA Department of Health Services (DHS) water quality testing sites along the permiter of Avalon Bay.*




FIB log-means and standard deviations are presented in Figure K. The three columns in this figure correspond to the three FIB groups (ENT, EC, and TC). The rows correspond to the five DHS sampling sites (DHS 117, 118, 119, 120, and 121). The three data points plotted in each graph correspond to the log-mean (and standard deviation) of bacteria concentrations measured before, during, and after the moratorium.

**Figure K.** *Mean and standard deviations of log-transformed fecal indicator bacteria concentrations measured at the five DHS sampling sites in Avalon Bay before, during, and after the wash-down moratorium.*




Based on the results presented in Figure K, water quality at three sites (DHS 117, 118, and 119) improved during the moratorium:

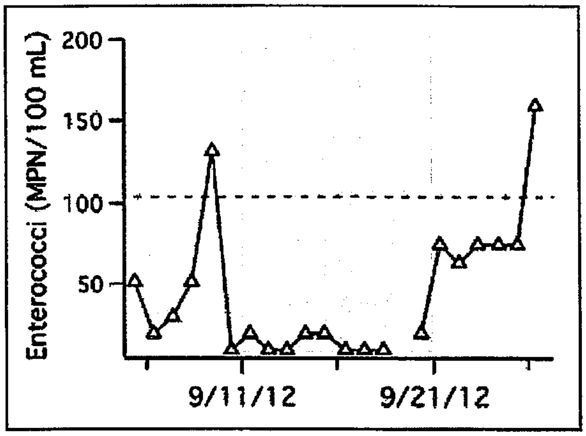
(1) At DHS 117, ENT concentrations were significantly lower during the moratorium, compared to before and after the moratorium.

(2) At DHS 118, ENT concentrations were significantly lower during the moratorium, compared to before or after the moratorium. Additionally, TC and EC concentrations were significantly lower during the moratorium, compared to after the moratorium.

(3) At DHS 119, TC and EC concentrations were significantly lower during the moratorium, compared to before or after the moratorium (although, in this case, the standard deviations are large for log-mean TC and EC concentrations measured before the moratorium).

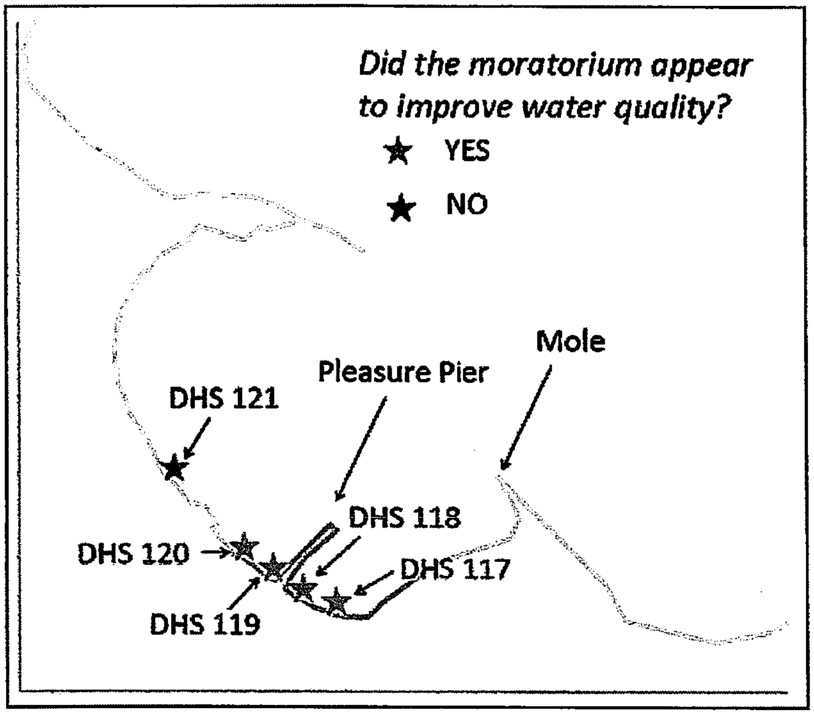
To illustrate the change in water quality observed at one of these sites, the concentration of ENT measured at site DHS 118 is presented in Figure L. At this site, the measured ENT concentration was highly variable before and after the moratorium. However, during the moratorium, the ENT concentration was near or below the lower-detection limit (10 MPN/100 mL).

**Figure L.** *The concentration of enterococci bacteria maesured at DHS 118 before, during, and after the wash-down moratorium. The time period of the 10-day wash-down moratorium is indicated by grey shading. The dashed line indicates the single sample marine bathing water criteria for enterococci bacteria (104 MPN/100ml).*




Interestingly, the sites where water quality appeared to improve during the moratorium (DHS 117, 118, and 119) are located close to the Pleasure Pier and the Mole, where bird droppings are routinely washed into Avalon Bay (Figure M). The two DHS monitoring sites (DHS 120 and 121) where water quality did not improve during the moratorium are located relatively far away from areas where bird droppings are routinely washed into the Bay. Taken together with the two bird dropping studies conducted as part of earlier grants (including the bird marker study, Figure I), the wash-down moratorium results presented here support the hypothesis that bird droppings are a significant source of FIB at some DHS sampling sites in Avalon Bay.

**Figure M.** *Location of DHS sampling sites where the wash-down moratorium appeared to improve water quality (red stars). These sites are located nearest areas (Pleasure Pier and Mole) where bird droppings are routinely washed into Avalon Bay.*




(b) Environmental Reservoirs of Fecal Indicator Bacteria

In addition to sewage, runoff, and bird droppings there are a number of environmental reservoirs of FIB that could influence the water quality of Avalon Bay. To set the stage for this discussion, it is helpful to understand why FIB are used as a measure of bathing water quality. In short, their adoption was motivated by the observation that FIB are present at high concentrations in human sewage, and hence their presence in recreational waters might "indicate" the presence of sewage contamination.[10] This observation has been reinforced over the years by numerous epidemiological studies, conducted around the world, that indicate a dose-response relationship between recreational exposure to marine bathing waters harboring high concentrations of FIB (in particular, enterococci bacteria) and adverse human health outcomes, including gastrointestinal illness.[11] While these dose-response relationships are robust in marine waters contaminated by sources of human sewage (e.g., an outfall just offshore of the beach discharging partially treated sewage), the epidemiological studies conducted at "beaches with nonpoint source pollution are fewer and have mixed success in correlating [FIB] abundance to bather health outcomes of enteric illness, respiratory, and skin infections."[12] Non-point sources of FIB include bird/animal droppings and urban runoff, as well as environmental reservoirs such as sand and decaying plant material. The last two are the focus of this discussion.

At California's coastal beaches, sand is a near-ubiquitous reservoir of FIB, and in particular enterococci bacteria.[13 14] Possible reasons for this include:

(1) Sand provides a protective environment for FIB relative to sunlight/UV inactivation, buffered pH and temperatures, and availability of nutrients accumulated from algae, debris, and plankton.

(2) The tendency of FIB to associate with particulate matter, which can accumulate in the interstices of sand.

(3) The fact that beach sand is a net sink for FIB from a variety of sources, including bird and animal droppings, nuisance runoff, stormwater runoff, sanitary sewage overflows, and bather shedding.[15]

Avalon Bay beaches are no exception to this rule. As part of a previous Clean Beaches Initiative study, samples of foreshore sediments were collected from a number of locations along the Avalon Beach shoreline, from DHS 117 to DHS 121.[16] In many cases, the concentration of FIB was higher in samples of beach sand, than in simultaneously collected samples of ankle depth water. FIB concentrations were consistently elevated in beach sands in front and upcoast of the Armstrong's Wharf, and downcoast of the Pleasure Pier. The origin of bacteria in Avalon's beach sand is unknown, but possibilities include:

(1) Exfiltration of sewage-contaminated shallow groundwater across the beach face at low tides.

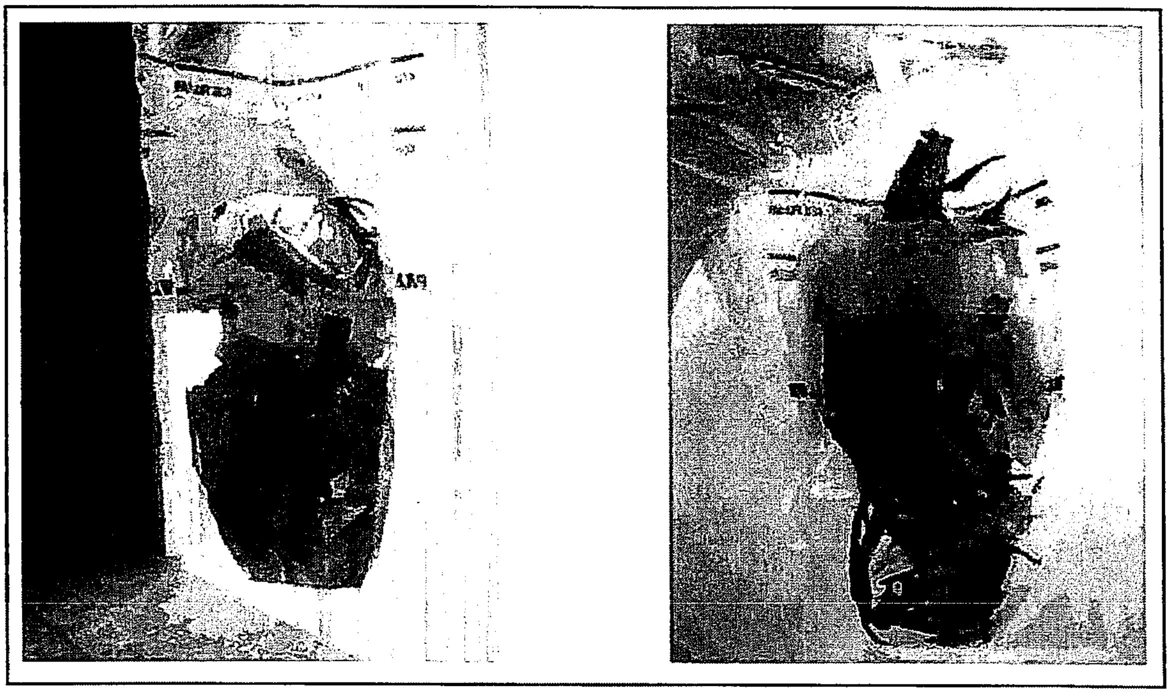
(2) Accumulation and sequestration of FIB from non-point sources such as nuisance runoff and bird droppings.[17] [18]

(3) Environmental growth of FIB on organic material, in particular decaying seaweed and trash associated with wrack lines that accumulate in the foreshore area.[19]

Beach sand and wrack lines can serve as a primary source of environmentally adapted FIB, and/or as a reservoir for FIB and human pathogens from other sources, such as sewage, bird droppings, and runoff.[20]

In Avalon Bay, the wrack lines consist primarily of trash, bird feathers, and decaying kelp. Wrack lines tend to accumulate along the shoreline in Avalon Bay during easterly swells when large waves propagate into Avalon Bay. As part of the studies conducted this past summer, samples of the wrack line were collected, resuspended in distilled water, and tested for FIB (TC, EC, and ENT) using Colilert-18 and Enterolert, following standard procedures. Suspension of roughly 10g of wrack line into 100 mL of distilled water resulted in TC, EC, and ENT concentrations of >24,196, 727, and 200 MPN/100 mL respectively. These bacterial concentrations exceed the respective single-sample marine bathing water criteria (10,000, 400, and 104 MPN/100 mL), lending credence to the idea that wrack lines could contribute to the water quality problem in Avalon Bay. A picture of the debris associated with wrack line materials collected from Avalon Bay on 9/12/12 is presented in Figure N.

**Figure N.** *Wrack line specimens collected from the shoreline in Avalon Bay.*



3. **MS4 System.**

(a) <u>MS4: Downtown Drainage and Avalon Canyon</u>

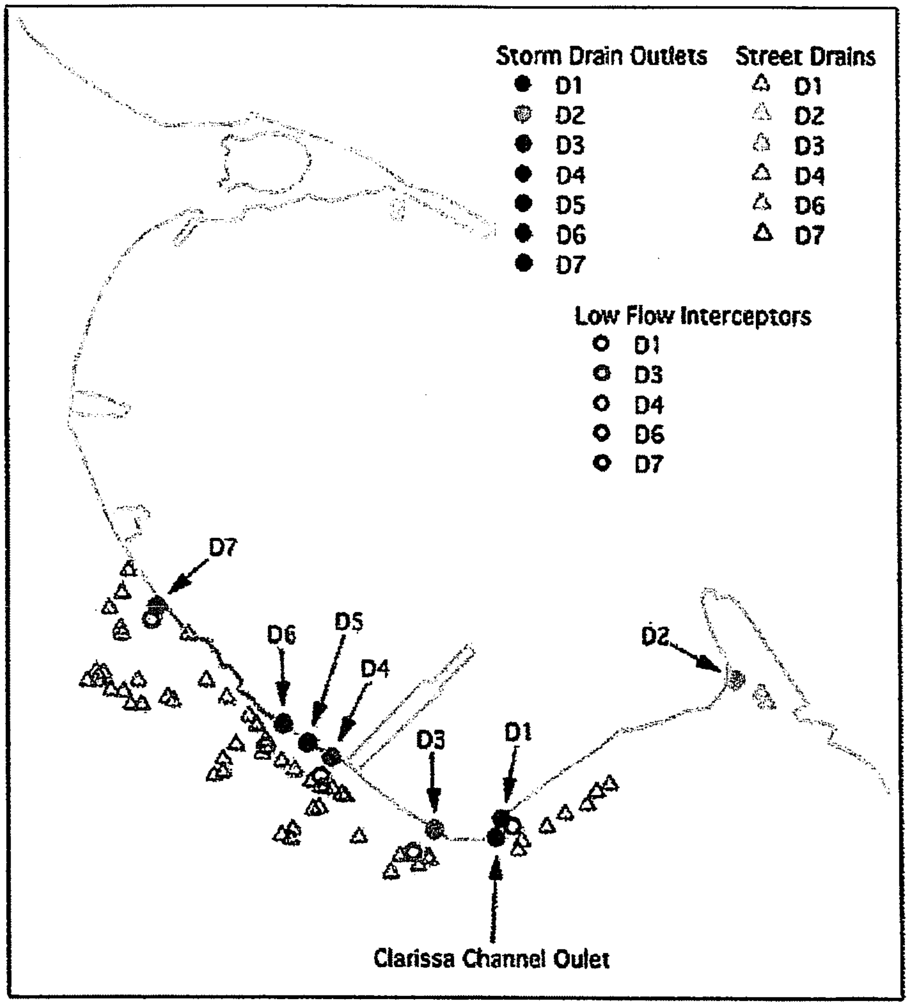
In addition to the POTW and the collection system, Avalon owns and operates a municipal separate storm sewer system (MS4). The MS4 consists of two main components:

(1) A flood control channel that drains Avalon Canyon.

(2) A network of street drains, roof drains, subsurface pipes, and low-flow interceptors that collectively drain the downtown area.

The flood control channel (referred to here as the Clarissa Channel) discharges to the southeast corner of Avalon Bay. The downtown drainage is divided into seven sub-drainages (D1 through D7) that discharge through storm drains distributed around the perimeter of Avalon Bay (Figure O). These MS4 drainage systems are described next.

**Figure O.**




*Sub-drainage D1*: Sub-drainage D1 captures runoff from at least seven street drains located along Pebbly Beach Road, between Crescent Avenue and the Mole Parking Lot. The sub-drainage has a low-flow interceptor designed to divert dry-weather "nuisance" runoff (generated, for example, by overwatering of lawns and street wash down activities) to the sanitary sewer system. During wet weather, sub-drainage D1 receives storm water runoff from the hillside area bordering Pebbly Beach Road between Crescent Avenue and the Mole Parking Lot, and from the park and hillside areas located south of the Catherine Hotel. When stormwater runoff exceeds the capacity of the low-flow interceptor, runoff is discharged to Avalon Bay through a storm drain located at the shoreline, approximately 15 feet northeast of the Clarissa Channel outlet.

*Sub-drainage D2*: Sub-drainage D2 captures runoff from at least two drains in the Mole waiting area; this sub-drainage does not have a low-flow interceptor. Observations during the summer of 2012 suggest that dry weather nuisance runoff generated by this sub-drainage (most likely from the wash-down of the Mole facility) is discharged to Avalon Bay through a storm drain located near Gate 3 at the Mole. During wet weather, this sub-drainage receives runoff from exposed areas and the rooftops at the Mole facility. Because birds congregate on the rooftops, this sub-drainage will probably contribute bird droppings (and associated FIB) to Avalon Bay during storm events and possibly during wash-down activities.

*Sub-drainage D3*: Sub-drainage D3 captures runoff from at least five street drains located near the intersection of Crescent Avenue and Clarissa Avenue. The sub-drainage has a low-flow interceptor, and thus dry weather nuisance runoff should be diverted to the sanitary sewer system. During wet weather, sub-drainage D3 receives storm water runoff from the highly developed (commercial) area bordering Clarissa Avenue, which includes impervious surfaces (e.g., paved roads) and rooftops. When the flow of surface runoff exceeds the capacity of the low-flow diverter, excess runoff is discharged to Avalon Bay through a storm drain located at the shoreline, approximately 300 feet west of the Clarissa Channel outlet. Because birds congregate on the rooftops of downtown businesses, this sub-drainage probably contributes bird droppings (and associated FIB) to Avalon Bay during storm events.

*Sub-drainage D4*: Sub-drainage D4 captures runoff from at least sixteen street drains located along Crescent Avenue and Catalina Avenue near the foot of the Pleasure Pier. The sub-drainage has a low-flow interceptor, and thus dry weather nuisance runoff should be diverted to the sanitary sewer system. During wet weather, sub-drainage D4 receives storm water runoff from the highly developed (commercial) area bordering Catalina Avenue, which has both impervious surfaces (paved roads) and rooftops. When the flow of surface runoff exceeds the capacity of the low-flow diverter, excess runoff is discharged to Avalon Bay through a storm drain located along the shoreline, approximately 30 feet northwest of the Pleasure Pier. Because birds congregate on the rooftops of downtown businesses, this sub-drainage probably contributes bird droppings (and associated FIB) to Avalon Bay during storm events. If good housekeeping steps are not taken, the Vista Del Mar building could also contribute trash and FIB to Avalon Bay during storm events.

*Sub-drainage D5*: This sub-drainage drains only the rooftop of the Vista Del Mar building. Water from the rooftop accumulates in an underground vault, which is buried in the sand at the upper beach and located approximately 300 feet northwest of the Pleasure Pier. If the volume of runoff form the Vista Del Mar roof exceeds the capacity of the buried vault, runoff will overflow into the surrounding sand, and flow by surface and subsurface pathways to Avalon Bay.

*Sub-drainage D6*: Sub-drainage D6 captures runoff from at least 20 street drains located near Crescent Avenue between Sumner Avenue and Whittley Avenue. The sub-drainage has a low-flow interceptor, and thus dry weather nuisance runoff should be diverted to the sanitary sewer system. During wet weather, sub-drainage D6 receives storm water runoff from the highly developed (commercial and residential) low-elevation and hillside areas along, and adjacent to, Sumner and Whittley Avenues. This drainage area has both impervious surfaces (paved roads) and rooftops. When the flow of surface runoff exceeds the capacity of the low-flow diverter, excess runoff is discharged to Avalon Bay through a storm drain located along the shoreline, approximately 600 feet southeast of the Armstrong Wharf. Because birds congregate on the rooftops of downtown businesses and homes, this sub-drainage probably contributes bird droppings (and associated FIB) to Avalon Bay during storm events. Sumner Avenue carries high volumes of storm water during large storms.

*Sub-drainage D7*: Sub-drainage D7 captures runoff from at least six street drains located along Crescent Avenue between the Armstrong Wharf and the Tuna Club. The sub-drainage has a low-flow interceptor, and thus dry weather nuisance runoff should be diverted to the sanitary sewer system. During wet weather, sub-drainage D7 receives storm water runoff from the mixed-use (undeveloped, commercial and residential) flat and hillside areas north of Marilla Avenue. When the flow of surface runoff exceeds the capacity of the low-flow diverter, excess runoff is discharged to Avalon Bay through a storm drain located along the shoreline, approximately 600 feet northwest of the Armstrong Wharf. Because birds congregate on the rooftops of downtown businesses and homes, this sub-drainage probably contributes bird droppings (and associated FIB) to Avalon Bay during storm events.

*Clarissa Channel and Avalon Canyon*. Avalon Canyon is one of the largest Catalina Island watersheds. It extends approximately one mile southwesterly from the City, and drains approximately 4 square miles of mixed land-use, including undeveloped land, a golf course, a botanical garden, a campground, Avalon City Hall, and scattered residential and commercial buildings. Early in the City's history, the natural drainage of Avalon Canyon was altered by the construction of a drainage system that diverted all runoff to a partially lined channel (the Clarissa Channel) located along the eastern flank of the canyon. While largely successful as a flood control measure, the constructed drainage system changed natural hydrological processes (e.g., ponding, infiltration, and evapotranspiration) that would otherwise reduce the volume, and slow the flow, of stormwater runoff to Avalon Bay.[21] During moderate to large storms, more than 90% of the total runoff volume discharged to Avalon Bay could come from Avalon Canyon, compared to less than 10% from the highly developed downtown area.[22] Therefore, relative to the FIB TMDL, plans to meet the wet weather WLA must take into consideration the possible water quality impact of stormwater runoff from Avalon Canyon.

In the downtown area, the Clarissa Channel drains some adjacent commercial and residential areas, and it is below ground for a short distance (approximately 600 feet) landward of Avalon Bay. A low-flow interceptor is installed in the bottom of the channel, upstream of the below ground section. Thus dry weather nuisance runoff in the downtown section of the Clarissa Channel should be captured and diverted to the sanitary sewer system.

(b) MS4: Loading

The loading ($L$) of FIB to Avalon Bay from the MS4 system depends on the concentration of FIB in the runoff ($C$ ) and the flow rate (volume per time) of runoff discharged to the Bay ($Q$): $L = C*Q$. The two key variables in this formula ($C$ and $Q$) are discussed next for dry weather (nuisance runoff) and wet weather (stormwater runoff) conditions.

(c) MS4: Nuisance Runoff

The volume of dry weather (nuisance) runoff entering Avalon's MS4 drainage is unknown, but likely varies by time of day, in accordance with daily patterns in the watershed, such as irrigation practices and wash down of sidewalks and streets, among others. While the volumes of runoff generated by these activities may be small, the concentration of FIB in the runoff can be very large. As part of a Clean Beaches Initiative study conducted during the summers of 2000 and 2001, samples of nuisance runoff were collected from various locations in downtown Avalon and analyzed for FIB using the procedures adopted by L.A. Department of Health Services for their routine sampling of Avalon Bay (IDEXX Colilert-18 and Enterolert). The concentrations of total coliform, fecal coliform (*E. coli*), and enterococci bacteria in these samples were near, or above, the detection limit (>24,192 MPN/100 mL). To put this result in perspective, the measured concentrations of enterococci bacteria are between 10 and >240 times greater than the marine bathing water single-sample criteria of 104 MPN/100 mL. Coupled with the very low dilutions that occur as nuisance runoff flows into an enclosed embayment,[23] the conclusion is that nuisance runoff can cause water quality exceedences along the shoreline, *provided it reaches the Bay*. Based on field observations during the summer of 2012, the low flow interceptors appear to be functioning properly in the sub-drainages where they are installed (D1, D3, D4, D6, D7), and therefore nuisance runoff does not appear to be flowing to the shoreline at these locations. Nuisance runoff is discharged to the Bay at subdrainage D2 (the Mole drainage) and sub-drainage D5, where depending on flow rates, the underground vault can overflow and potentially impact Bay water quality. Because of the low flow ~~interceptors,~~ nuisance runoff does not ~~appear to be a large contributor to the~~ water quality problem in Avalon Bay.

This last conclusion—that nuisance runoff is not a large contributor to the water quality problem in Avalon Bay—is reinforced by salinity measurements in Avalon Bay. During the field studies conducted in the summer of 2012, a set of 10 conductivity and temperature sensors were installed around the perimeter of Avalon Bay. The sensors were tethered to floats and swim lines, such that the sensing window was located approximately 1 foot below the water surface in approximately 3 to 6' deep water (depending on the tide and location). Analysis of these data is ongoing, but initial results indicate that the salinity of nearshore waters of Avalon Bay cycles between ocean salinities during high tides (~33 p.s.u.), and brackish (>25 p.s.u.) salinity during low-tides. The freshwater signal observed during low tides appears to be associated with the submarine discharge of meteoric groundwater during low tides. Importantly, the salinity measurements in Avalon Bay are not consistent with the (non-tidal and likely random) patterns that would be expected if significant volumes of nuisance (dry weather) runoff were being discharged to Avalon Bay through the City's MS4 system. The conductivity sensor data collected during the summer of 2012 continues to be analyzed, with the goal of estimating a baseline discharge of meteoric groundwater to Avalon Bay against which storm discharges of surface runoff can be compared.

(d) MS4: Stormwater Runoff

According to Hamilton (1999),[24] annual rainfall in Avalon ranges from 4.1 to 30.5 inches. In a typical year, over 60 percent of Avalon's rainfall occurs in the winter period, from December through February. Given the drainage areas quoted above, it is a straightforward exercise to estimate the runoff volumes associated with any particular size storm. However, what is presently lacking is information on the concentration of FIB in stormwater runoff from Avalon Canyon and downtown Avalon. Such data will be obtained as part of the year-round sampling of Avalon Bay proposed under this TMDL Compliance Plan (see later).

C. Summary of Bacterial Residence Times in Shallow Groundwater Study

Paragraph 35 of the CDO requires the City to conduct a study to determine the residence time of "indicator bacteria populations in shallow groundwater underlying downtown Avalon and potential methods to reduce the bacteria populations." This Section 2.C of the Compliance Plan provides a summary of the science studies conducted during the summer of 2012 to address this requirement.

1. **Background and Motivation**

A previous Clean Beaches Initiative study of Avalon Bay found high concentrations of FIB in shallow groundwater collected from trenches dug along the Avalon Bay shoreline, and some of these water samples tested positive for molecular markers of viruses and bacteria associated with human feces. This earlier study, which was published in 2003, suggested that the shallow groundwater underlying the City is possibly "contaminated with sewage, probably from a leaking sewer trunk line."[25] A follow-up Clean Beaches Initiative study,[26] completed in 2010, found multiple lines of evidence "consistent with the hypothesis that [FIB] concentration along the shoreline in Avalon Bay is caused, at least in part, by the discharge of sewage-contaminated shallow groundwater into the Bay." Another study, conducted by Professor Alexandria Boehm's research group at Stanford University and completed in 2009, concluded that the co-variation of different markers of fecal pollution (specifically enteroccoci bacteria, *E. coli*, and F+ coliphage) was consistent with a common source for these organisms in Avalon Bay, presumed to be "leaking sewage lines."[27] These earlier scientific studies are consistent with the $SF_6$ tracer studies presented earlier in this Compliance Plan, which indicate that problems exist with the Bay Side Plumbing and also with closed circuit TV (CCTV) videos of the sewage collection system beneath the City that revealed a number of instances (now corrected) where the integrity of sewer lines, before the City's recent upgrade project, appeared compromised.

As these findings have come to light, the City has moved aggressively to repair and replace damaged sections of the sewage collection system, spending $5.7 million in infrastructure repairs this past year alone. It is anticipated such repairs will eliminate sewage leaks to the shallow groundwater beneath the City. This goal is consistent with the TMDL for Avalon Bay, which ultimately allows for zero exceedances of the geometric mean and single-sample numeric targets due to discharges from the POTW and, by June 30, 2015, its associated collection system.

While repair of the Bay Side Plumbing is a necessary remaining step for improving shoreline water quality in Avalon Bay, one major unknown concerns the length of time it will take before the shallow groundwater is cleaned up by natural processes. Past leaks in the collection system could have, over time, added nutrients (e.g., nitrogen and phosphorous) and organic carbon to the shallow groundwater.[28] This legacy pollution may support the survival, and perhaps even growth, of environmentally adapted strains of FIB.[4, 29] In turn, the growth of FIB in the shallow groundwater could cause continuing exceedances of single-sample and geometric mean numeric targets in the nearshore waters of Avalon Bay, even after all major repairs have been completed.

The studies presented here are intended to evaluate the residence time of FIB in the shallow groundwater beneath the City, consistent with the requirements of paragraph 35 of the CDO.

## 2. Residence Time Studies

To assess the persistence of FIB in shallow groundwater beneath the City, two complementary approaches were employed. First, the length of time it takes a passive tracer ($SF_6$) to transport from leaks in Bay Side Plumbing, through the shallow groundwater and into Avalon Bay was examined. The resulting transport time scales (*T*) indicates how quickly shallow groundwater beneath the City of Avalon is flushed by natural hydrogeological processes, including the subsurface flow of meteoric groundwater toward the Bay and tidal movement of Bay water into and out of the shallow groundwater. Second, concentrations of FIB were measured at multiple depths in the shallow groundwater at the five DHS sampling sites (DHS 117 through 121) . These latter data shed light on the persistence of FIB in the subsurface, independent of hydrogeological processes that potentially transport sewage and bacteria in the subsurface. Together, these two complementary approaches shed light on the time-scales over which shallow groundwater is likely to be contaminated with FIB. Furthermore, these results help clarify the need for, and potential design of, a subsurface remediation strategy to clean-up legacy sewage-related pollution in the shallow groundwater beneath the City. Results of these two studies are described next.

### (a) Physical Residence Time in the Shallow Groundwater

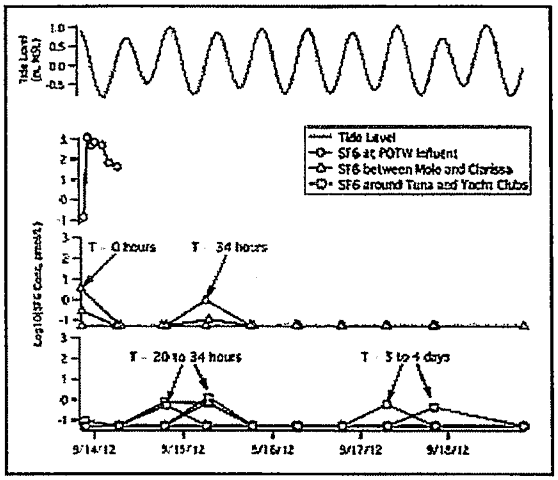
Here the goal was to ascertain the physical residence time of water parcels as they travel from leaks in the Bay Side Plumbing, through the shallow groundwater, and into Avalon Bay. To this end, the timing of $SF_6$ positive samples collected in Avalon Bay was examined. As noted earlier, $SF_6$ positive samples clustered into two primary groups:

(1) Samples collected between the Mole and Clarissa Channel.

(2) Samples collected around the Yacht Club and Tuna Club.

The timing of $SF_6$ positive samples in these two areas of Avalon Bay is indicated in Figure P. Between the Mole and Clarissa Channel, $SF_6$ appeared in two distinct pulses: within one hour after the addition of the tracer ($T$~1 hour), and again approximately a day-and-a-half later ($T$~36 hours). Likewise, in the area around the Tuna Club and Yacht Club, $SF_6$ was detected in two pulses: an initial pulse one-to-two days after the addition of tracer ($T$~20 to 34 hours), and again two-to-three days later ($T$~3 to 4 days).

**Figure P.** *Timing of SF6 positive samples at three locations: (A) Influent to POTW; (B) Avalon Bay between Mole and Clarissa Channel; and (C) Avalon Bay around Tuna Club and Yacht Club.*




The fact that two pulses were observed at both sites could imply the existence of multiple leaks at each site with different set-back distances from the beach, or it might reflect the influence of tides on the discharge of shallow groundwater to Avalon Bay (a tide chart is also displayed in Figure P). In any case, what can be said from these results is that subsurface sewage leaks are transported very rapidly toward the beach, within hours at some sites (between the Mole and Clarissa Channel) and within days at other sites (around the Tuna Club and Yacht Club). Interestingly, the substrate between the Mole and Clarissa Channel consists, at least in part, of extremely porous and permeable riprap, which may explain the very rapid Bay-ward transport of $SF_6$ in this area. The substrate around the Yacht Club and Tuna Club, on the other hand, consists primarily of well-graded and unconsolidated sands, gravels, and cobbles that, while still quite permeable, are less so than riprap, and thus likely to result in slower Bay-ward transport of shallow groundwater. In summary, within the resolution of the $SF_6$ experiment, a physical residence time of sewage in the shallow groundwater of hours to days is indicated.

(b) <u>Residence Time of Fecal Indicator Bacteria</u>

Given the very short residence times described above, it might be concluded that FIB concentrations in the shallow groundwater will decline rapidly, perhaps within weeks, once all sewage leaks are repaired. However, this presumes that FIB do not multiply in the subsurface (i.e., they are "conservative", like the $SF_6$ tracer). As noted, FIB survive, and even grow, in the protective and nutrient-rich environment conferred by sediment and sand. To address the degree to which FIB have taken up residence in the shallow groundwater beneath the City, a series of groundwater wells were installed at the five Department of Health Services sampling sites (DHS 117 to 121) located around the perimeter of Avalon Bay.

Previous attempts to measure FIB in the shallow groundwater beneath the City have met with variable success. In the original Clean Beaches Initiative study conducted in

2000/2001, water samples collected from shallow trenches dug in the foreshore of the main beach had very high, but highly variable, concentrations of FIB.[30] [31] While these measurements might have been reflective of the FIB concentrations present in the shallow groundwater, they could also have been an artifact of digging the trenches; namely, in the course of digging trenches, bacteria in surficial beach sands are unavoidably mixed into groundwater samples collected from the trenches. In the follow-up Clean Beaches Initiative study, this potential artifact was addressed by the installation of 27 shallow groundwater wells, twenty of which were arrayed in a "picket line" along the Avalon Bay shore, from DHS 117 to DHS 121. The vast majority of groundwater samples collected from these wells had FIB concentrations below the lower-limit of detection for the tests employed (<10 MPN/100 mL). Of the groundwater samples that had FIB concentrations above the detection limit, many came from wells installed near Step Beach (DHS 121) and Armstrong's Wharf (DHS 120). That relatively few wells yielded groundwater with elevated FIB (despite the historical existence of sewage leaks (now corrected) documented in this Compliance Plan and in previous studies) may be a consequence of the highly localized nature of FIB contamination in the subsurface. For example, electrical resistivity tomography studies conducted as part of the second Clean Beaches Initiative grant revealed that the shallow groundwater beneath the City is spatially heterogeneous. Together with the groundwater sampling results, the conclusion is that, to the extent that the shallow groundwater beneath Avalon is contaminated with sewage, the contamination is localized in both the horizontal and vertical dimensions.[32]

To better pin point sewage contamination potentially present in the shallow groundwater beneath Avalon, groundwater wells installed during the summer of 2012 were designed to sample water from varying depths. Specifically, at each of the five Department of Health Services sampling sites, a "nest" of five wells were installed ranging in depth from 5' to 9' below ground surface (Figure Q). Each well consisted of 3/4" stainless steel pipe, terminating in a stainless steel well point. Groundwater enters the well through screens in the well point, which is connected to a 5/8" tube, or "liner", that prevents groundwater from coming into direct contact with the inside of the well casing. Wells were assembled off site, and then pounded into the sand to a prescribed depth by City Public Works staff (supervised by Mr. Pastor Lopez) using a manual slide hammer (Figure R). Installation of the wells proved challenging, due to the presence of cobbles and boulders in the sand, equipment failure, the large numbers of beach goers (including young children) present at the installation sites, and multiple (and often contradicting) timing constraints imposed by limits on noise (work could only be conducted after 8AM), the requirement for low tide conditions (which typically occurred early in the morning), and availability of staff. Despite these challenges, installation of all 25 shallow groundwater wells (five at each site times five sites) was completed in mid-September (2012). Sampling and testing of the shallow groundwater commenced as each nest of five wells came online.

**Figure Q.** *Schematic diagram showing the "nest" of five groundwater wells installed at each of the five DHS sites (DHS 117 to DHS 121).*

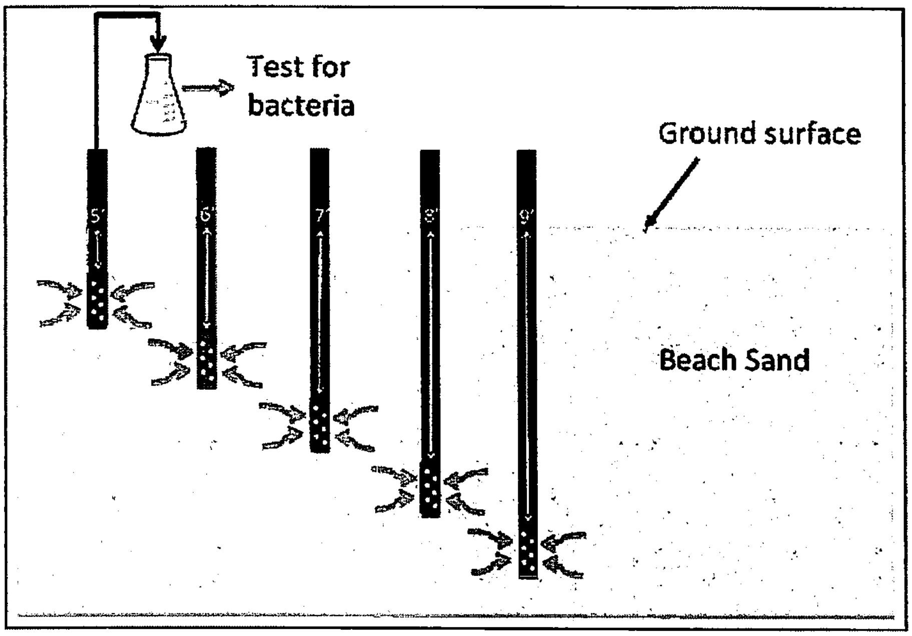



**Figure R.** *Manual installation of one of the shallow groundwater wells by City of Avalon Public Works staff. The wells were pounded into the sediment down to a prescribed depth using a slide hammer (the black device at the top of the well.).*

Groundwater samples were collected by threading a ¼" Teflon "drop tube" down the well liner, and drawing the groundwater sample to the surface with a battery powered peristaltic pump (Solinst Corporation). In the first several days after a well was installed, relatively little water could be withdrawn from the well, and the produced water was very turbid. However, over the course of several days post well installation, the turbidity of groundwater samples declined, and the volume of water produced increased. Samples of the turbid water initially produced by the wells had high concentrations of FIB, probably associated with surficial sands that were pulverized and mixed downward during well installation. Thus, the groundwater testing results presented below only include samples collected after the produced groundwater was no longer (visibly) turbid. To ensure the sample consisted of fresh groundwater (and not water that had been sitting in the well liner), the drop tube and liner were purged for several minutes prior to collecting a groundwater sample. Every time the drop tube was withdrawn from a well, it was thoroughly rinsed and flushed with distilled water. A field blank (consisting of distilled water pumped through the drop tube with the peristaltic pump) was collected, to ensure no measureable FIB were carried over from the previous well. At the end of each day, the drop tube was discarded and replaced with a fresh one. Groundwater samples were collected in 100 mL Whirlpak bags, containing sodium thiosulfate to neutralize disinfectants potentially present in the sample. After collection, the water samples were immediately placed on ice, transported to the field laboratory located at Avalon City Hall, and tested within a holding time of three hours for enterococci bacteria (ENT), *E. coli* (EC), and Total Coliform (TC) using IDEXX Colilert-18 and Enterolert, following standard procedures.

Groundwater samples were collected from each nest of wells over three to six consecutive days as follows (all dates 2012):

DHS 117: 9/17, 9/18, 9/19
DHS 118: 9/8, 9/9, 9/10, 9/11, 9/12
DHS 119: 9/7, 9/8, 9/9, 9/10, 9/11, 9/12
DHS 120: 9/17, 9/18, 9/19
DHS 121: Pending

Apart from the well nest at DHS 121 for which no data are presently available, the concentrations of FIB in these wells were generally below the respective marine bathing water criteria of 104, 400, and 10,000 for ENT, EC, and TC, respectively (Figures S, T & U). The two exceptions are EC concentrations measured in water samples collected from 7 feet below ground surface at DHS 119 (Figure T), and TC concentrations 9 feet below ground surface at DHS 118 (Figure U). Based on these results, the shallow groundwater beneath the City appears to have relatively low concentrations of FIB. To the extent that FIB are present in the subsurface, they tend to be confined to be highly localized, present only at specific locations and depths (e.g., DHS 119 at 7' bgs, and DHS 118 at 9' bgs). It should be noted that testing has not yet been carried out at DHS 121; this site, located at Step Beach, yielded relatively high concentrations of FIB during the 2010 Clean Beaches Initiative-funded groundwater testing.

**Figure S.** *Concentration of enterococci bacteria (ENT) measured in shallow groundwater beneath the City of Avalon. Each symbol denotes the site and depth at which the groundwater sample was collected ("bgs"=below ground surface). The horizontal axis indicates the date and time the sample was collected.*

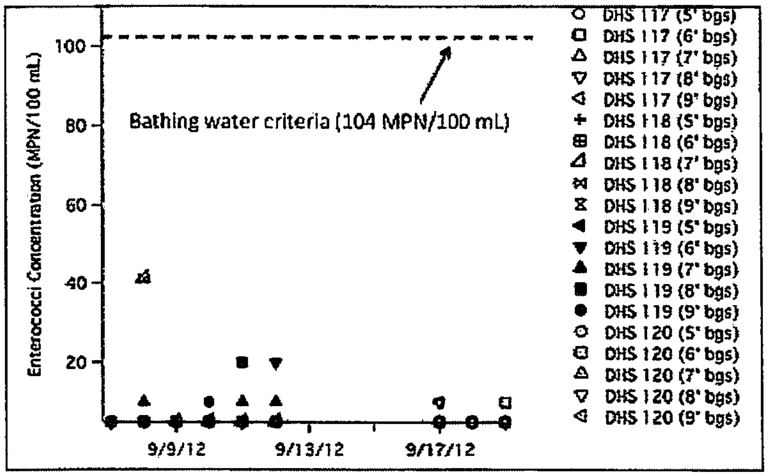



**Figure T.** *Concentrations of E. coli (EC) measured in shallow groundwater beneath the City of Avalon. Each symbol denotes the site and depth at which the groundwater sample was collected ("bgs" =below ground surface). The horizontal axis indicates the date and time the sample was collected. The red shading denotes a set of samples that were near, or above, the single sample standard for EC.*

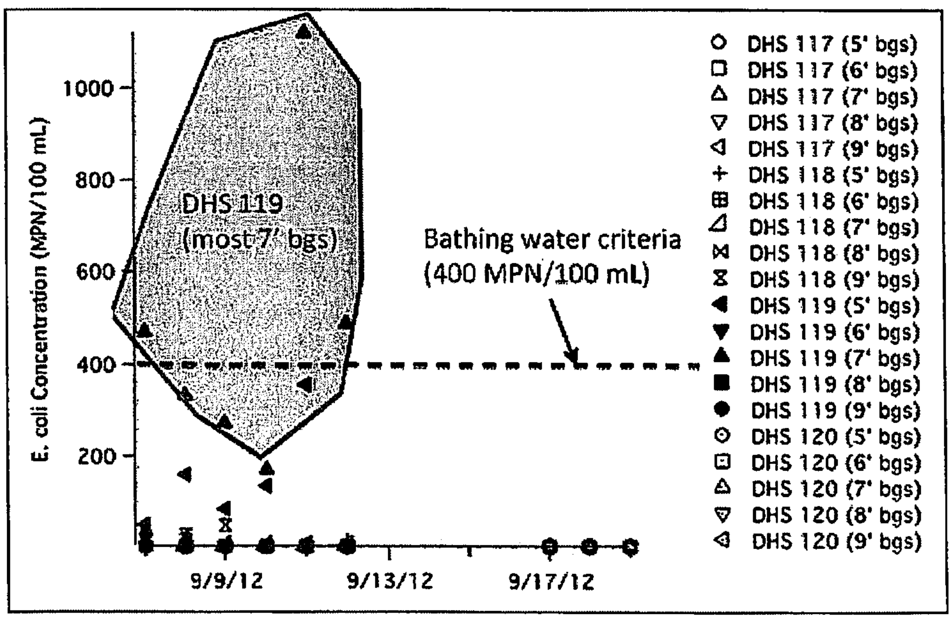
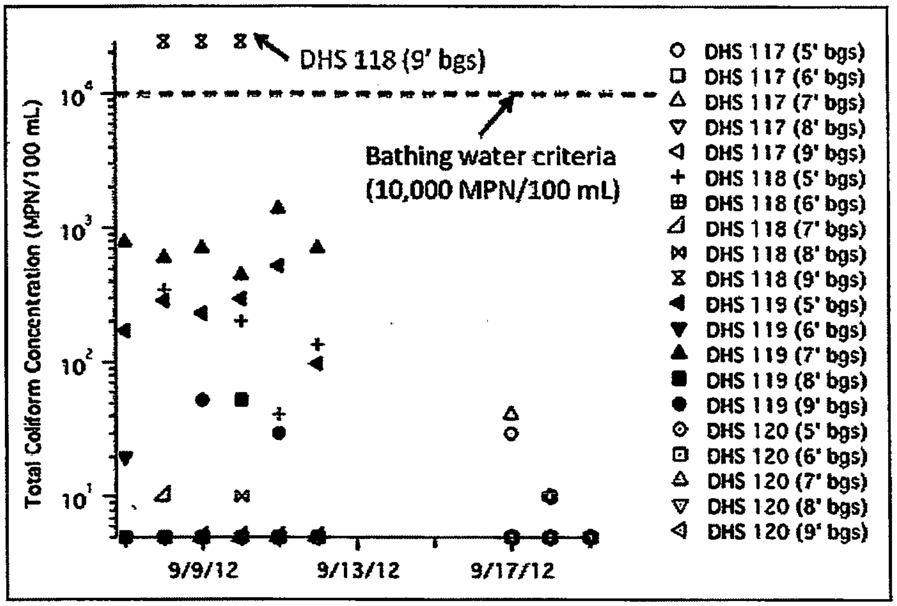


**Figure U.** *Concentration of Total Coliform (TC) measured in shallow groundwater beneath the City of Avalon. Each symbol denotes the site and depth at which the groundwater sample was collected ("bgs" =below ground surface). The horizontal axis indicates the date and time the sample was collected. Some samples collected at DHS 118 and TC concentrations above the upper-limit of detection (24,190 MPN/100ml).*




### 3. Summary of Residence Time Studies

Collectively, the data presented in this Section are consistent with the following conclusions:

(1) The physical residence time of water in the shallow groundwater is relatively short (hours to days), and thus hydrogeology in the subsurface is such that markers of sewage contamination (such as FIB) will tend to be flushed out of the shallow groundwater relatively rapidly.

(2) Perhaps consistent with the last point, there is little evidence of wide-spread contamination of the shallow groundwater with FIB.

To the extent that the shallow groundwater harbors FIB, the contamination tends to be confined to very specific locations and depths. These "pockets" of FIB contamination presumably reflect the location of ongoing leaks in Bay Side Plumbing, and the highly heterogeneous nature of flow paths in the subsurface as revealed by electrical resistivity tomography.

D. Load Reduction Options

Based on the science studies described above, a number of steps can be taken to reduce the loading of FIB to the shoreline waters of Avalon Bay. These are described below.

1. **Anthropogenic Sources.**

(a) Bay Side Plumbing

Based on the $SF_6$ tracer studies, it appears that sewage from the Bay Side Plumbing is still making its way into the shallow groundwater, and from there into Avalon Bay. Because $SF_6$ was added at 17 different sites, it is not possible to pinpoint specific sewage leaks, although the location and timing of $SF_6$ positive samples in the Bay provides important clues about where to focus. For example, the rapid appearance of $SF_6$ positive samples along the southeasterly border of the Bay is consistent with a sewage leak close to the shore in that region of the Bay. One obvious candidate is the lateral that conveys sewage from the bathrooms at the Mole facility to one of the sewer mains near the intersection of Clarissa and Crescent Avenue. Following the $SF_6$ results, CCTV inspection of this lateral identified several anomalies that warrant further investigation, and perhaps repair. Likewise, the cluster of $SF_6$ positive samples around the Tuna Club and Yacht Club points to one or more sewage leaks in this vicinity. Following the $SF_6$ results, CCTV inspections of the sewer laterals for public shower and bathroom facilities, the Tuna Club and the Yacht Club, identified a number of anomalies that continue to be explored; indeed, one of these anomalies has already been repaired. Using the $SF_6$ results to help focus CCTV inspections laterals appears to be an effective approach for identifying, and ultimately repairing, sewage leaks that may impact Bay water quality. Once Public Works staff are reasonably confident they have inspected and repaired all potential sources of sewage in the two primary $SF_6$ "hot spots", the Bay Side Plumbing can be re-challenged with $SF_6$, although perhaps employing fewer release sites to better constrain sewage leaks should $SF_6$ be detected in the Bay. One potential concern is an upcoming California ban on the atmospheric release of $SF_6$ (it is a strong greenhouse gas), which may limit its use for future field studies, or at least require a time-consuming exemption request.

(b) MS4 Loading

The MS4 system in Avalon poses a significant challenge relative to meeting the WLAs, particularly during wet-weather. On the positive side, over the past decade the City has moved proactively to install low-flow interceptors at most sub-drainages in the downtown area. Field observations suggest that the low-flow interceptors are working properly, and dry weather (nuisance) runoff is being diverted to the sanitary sewer system. There are several exceptions. One is sub-drainage D2, where several floor drains in the Mole facility discharge directly to a storm drain near Gate 3. Another is drainage D5 where a roof drain from the Vista Del Mar Hotel flows directly to a vault buried in the sand. Given the very high concentrations of FIB measured in nuisance runoff, the science supports addressing these two dry weather sources.

Reducing the load of FIB associated with stormwater runoff may be more problematic, because a very large percentage of the storm flow to Avalon Bay comes from the

Clarissa Channel, which drains most of Avalon Canyon. Bacterial concentration data on the stormwater runoff are lacking, but based on experience in other areas of southern California, it is likely that Avalon Canyon contributes the majority of both flow volume and bacterial load to Avalon Bay during medium-to-large storms. Tackling this problem might require rethinking the drainage system in Avalon Canyon. One possible solution was suggested in an entirely different context by Hamilton (1999),[33] who argued that stormwater from the Canyon could be captured, stored, and slowly added back to the groundwater by infiltration. In addition to providing a much-needed source of freshwater for the island (Hamilton's idea was to use the captured stormwater as a new source of water for irrigating an expanded golf course), this strategy would also slow the velocities and volumes of runoff to Avalon Bay during storms. The science supports better characterizing the concentration of FIB in stormwater runoff from Avalon Canyon, and perhaps conducting a feasibility study on the stormwater capture, storage and reuse scheme proposed by Hamilton. In addition, best management practices could be implemented within the downtown area to reduce the concentration of bacteria in stormwater runoff during storms (e.g., by regularly cleaning streets and roofs that drain to the MS4 system). Additional approaches that merit consideration include measures intended to capture and retain stormwater runoff locally, for example through low impact development, the installation of rainwater tanks, and "green" infrastructure, such as rain gardens and green roofs.

2. **Non-Anthropogenic Sources.**

(a) Bird Droppings

A number of lines of evidence support the idea that bird droppings contribute to the water quality problem in Avalon Bay. The scientific evidence includes:

(1) Very high concentrations of FIB measured in water samples contaminated with specimens of gull fecal matter.

(2) A strong correlation between FIB concentrations measured in and around Avalon Bay and the concentration of a genetic marker for bird droppings (*Catellicoccus marimammalium*).

(3) The fact that a wash-down moratorium resulted in significant water quality improvement at sampling sites located closest to areas where bird droppings are normally washed into the Bay.

After the results of the wash-down moratorium were released to the public, City staff contacted a falconer who specializes in the removal of pigeons and gulls. This individual has since implemented a number of programs for reducing the pigeon and gull populations in the City, and for relocating pigeons to the mainland. The falconer discovered that hundreds of pigeons were living and nesting under the Pleasure Pier, near sites DHS 118 and 119, where shoreline water quality is routinely very poor. In his first couple of weeks on the job, the falconer relocated to the mainland more than 300 pigeons that had nested under the Pleasure Pier; he is in the process of relocating what he estimates are several hundred more pigeons under the Pleasure Pier.

The science supports taking all reasonable measures to limit bird populations in the City, and thereby reducing the loading of bird feces into Avalon Bay. Practical steps the City can take include:

(1) Imposing a wash-down moratorium or other controls on all piers, boats, floats and facilities in and around Avalon Bay.

(2) Controlling bird populations using raptors and other measures.

(3) Relocating pigeons to the mainland.

(4) Sealing off cubbyholes in the undercarriage of the Pleasure Pier that serve as attractive nesting areas for birds.

(b) <u>Natural Sources</u>

A number of natural sources of FIB have also been identified, including the sequestration and possibly growth of environmentally adapted strains on decaying wrack lines and in the protective environment of surficial beach sands. Field observations suggest that wrack lines are most prevalent along the shoreline in Avalon Bay following easterly swells which propagate into the Bay, damage kelp beds, scour and resuspend decaying debris and trash off the bottom of the water column, and transport the debris to the shoreline where regrowth of bacteria could amplify FIB populations associated with bird droppings, sewage, and runoff. The science supports implementing a regular beach maintenance program, in which wrack line material is daily removed from the beach and the shallow waters along the shore. This best management practice was pilot tested over the summer of 2012.

### 3. Groundwater Load Reduction Strategies

As part of the 2010 Clean Beaches Initiative grant to the City, four different candidate remediation strategies for sewage-contaminated shallow groundwater were evaluated: (a) aeration alone, (b) aeration with brine, (c) aeration with peracetic acid (PAA), and (d) aeration with peroxymonosulfate, or "Oxone". The inclusion of brine was motivated by the thought that it might be an "environmentally friendly" reagent for disinfecting sewage-contaminated sediment, together with the fact that brine is a waste stream from the City's desalination plant. PAA was chosen because it produces little in the way of toxic disinfection by-products (DBPs) when mixed with seawater (it rapidly degrades into acetic acid, or vinegar), and it has been approved for discharge to sensitive marine waters. Oxone has not been tested in coastal marine settings, but appeared promising based on the fact that it is a potent biocide and, upon addition to water, its primary breakdown product is sulfate, which is already present at high concentrations in marine waters. These four different remediation strategies were tested in laboratory experiments, to determine how quickly *E. coli* (EC) and enterococci bacteria (ENT) were disinfected in raw Avalon sewage diluted 1:100 into various mixtures (with various final salinities) of fresh groundwater from an inland well, Avalon Bay water, and brine from the local desalination plant. Of the candidate disinfectants evaluated, only PAA appeared to warrant further investigation based on the fact that it rapidly removed EC and ENT (greater than three logs of removal in under 10 minutes upon exposure to 4-5 mg $L^{-1}$ PAA) and its limited potential for forming DBPs in brackish waters[34].

Based on the groundwater studies conducted thus far, it is not clear that in situ disinfection is a useful approach for remediating sewage-contaminated shallow groundwater beneath the City. There are several reasons for caution. First, analysis of the $SF_6$ studies reveals that the physical flushing of the shallow groundwater is relatively rapid (hours to weeks), and thus natural hydrogeological processes (shoreward flow of meteoric groundwater and tidal exchange between the groundwater and Bay) will tend to flush out contaminants in the subsurface over time, provided that environmentally adapted strains of FIB have not taken up residence in the shallow groundwater. Second, wells installed both during the a previous study in 2010, and more recently this past summer, reveal that FIB concentrations in the shallow groundwater are relatively low, and where FIB are present they tend to be confined to highly localized "pockets" of contamination that are probably associated with specific sewage leaks. Collectively, the physical residence time studies and FIB persistence studies are consistent with the hypothesis that the shallow groundwater will "clean itself" over time, provided that sewage leaks are found and eliminated. That said, there may be a few sites, including the location near DHS 119 where a FIB plume may be present 7' below ground surface, and near Step Beach where the previous study found evidence of sewage contamination in the shallow groundwater, where in situ disinfection may be a useful adjunct to ongoing efforts to find and repair sewage leaks in Bay Side Plumbing. For this reason, the City will complete the sampling and testing of shallow groundwater wells installed at Step Beach (DHS 121), and as warranted continue monitoring FIB concentrations there and at sites near the Pleasure Pier. If, over time, FIB concentrations at these sites continue to be near or above the single-sample criteria for ENT, EC, and TC, the City may, in consultation with the Regional Board, explore a limited pilot study involving injection of dilute solutions of PAA into subsurface zones characterized by high concentrations of FIB.

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[15] See *Halliday, E. and R.J. Gast (2011)*
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[22] *This calculation assumes 0.12 square miles for the developed area in downtown Avalon (compared to 4 square miles for Avalon Canyon), and that 100% of the rainfall volume is converted to runoff in the downtown area, while only 40% of the rainfall volume is converted to runoff in the Avalon Canyon, consistent with Los Angeles County Public Works convention: percent runoff from Canyon= (0.4*4sqm)/(0.4*4sqm+1.0*0.12sqm)=93%.*
[23] Grant, S.B. and B.F. Sanders (2010)
[24] Hamilton, P. (1999) "Avalon Canyon Groundwater Investigation Santa Catalina Island", a report submitted to the Santa Catalina Island Company on October 18, 1999.
[25] *Boehm, A.B., J.A. Fuhrman, R.D. Mrse, and S.B. Grant (2003) "Tiered Approach for Identification of a Human Fecal Pollution Source at a Recreational Beach: Case Study at Avalon Bay, Catalina Island, California"* Environmental Science and Technology *37: 673-680.*
[26] *Grant, S.B., R. Litton, L. Ho, J. Monroe, M. Bailey (2010) "Avalon Bay Water Quality Improvement Project, Catalina Island, California: A final report on Shallow Groundwater Characterization, Task B.1 of the Clean Beaches Initiative Grant", a report to the City of Avalon and the State Water Resources Control Board.*
[27] *Boehm, A.B., K.M. Yamahara, D.C. Love, B.M. Peterson, K. McNeill, K.L. Nelson (2009) "Covariation and photoinactivation of traditional and novel indicator organisms and human viruses at a sewage-impacted marine beach",* Environmental Science and Technology *43:8046-8052.*
[28] *Grant, S.B., R. Litton, L. Ho, J. Monroe, M. Bailey (2010) "Avalon Bay Water Quality Improvement Project, Catalina Island, California: A final report on Source Identification of FIB in Ankle Depth Waters in Avalon Bay, Task B.3 of the Clean Beaches Initiative Grant", a report to the City of Avalon and the State Water Resources Control Board.*
[29] *Surbeck, C.Q., S.C. Jiang, S.B. Grant (2010) "Ecological control of fecal indicator bacteria in an urban stream",* Environmental Science and Technology *44:631-637.*
[30] *Grant, S.B., R. Mrse, C. Jensen-McMullin, M. Bachman, A. Boehm, J. Fuhrman, B. Jones "Sources and mitigation of water quality impairment in Avalon Bay, Catalina Island, California" Report submitted to the City of Avalon and the State Water Resources Control Board Clean Beaches Initiative (March 27, 2006).*

[31] *Boehm, A. B. F., J.A.; Mrse, R.D.; Grant, S.B., Tiered approach for identification of a human fecal pollution source at a recreational beach: Case study at Avalon Bay, Catalina Island, California. Environmental Science & Technology 2003, 37, (4), 673-680*

[32] *Grant, S.B., R. Litton, L. Ho, M. Bailey, J. Monroe, S. Wuertz, L. Liu, "Avalon Bay Water Quality Improvement Project, Catalina Island, California: A final report on Shallow Groundwater Characterization, Task B.1 of the Clean Beaches Initiative Grant", submitted to the City of Avalon and the State Water Resources Control Board (August 24, 2010).*

[33] Hamilton, P. (1999) "Avalon Canyon Groundwater Investigation Santa Catalina Island", a report submitted to the Santa Catalina Island Company on October 18, 1999.

[34] *Bailey, M.M., W.J. Cooper, S. B. Grant (2011) "In situ disinfection of sewage contaminated shallow groundwater: A feasibility study"* Water Research *45:5641-5653.*

## SECTION 3. IMPLEMENTATION METHODS

A. General Load Reduction Strategy.

The City intends to achieve compliance with the WLAs by using a variety of implementation strategies identified in this Section 3 of the Compliance Plan. Broadly speaking, these load reduction strategies focus on the following:

(1) Continuing to improve operations of the POTW to maintain compliance with NPDES permit requirements and to achieve the POTW "no exceedance" WLA.

(2) Continuing to improve operations and maintenance of the City's collection system, as well as addressing problems with private laterals and, in particular, Bay Side Plumbing, to achieve compliance with the June 30, 2015 collection system "no exceedance" WLA.

(3) Addressing, to the maximum extent practicable, discharges from the City's MS4 to assist in the achievement of the April 1, 2016, November 1, 2016 and November 1, 2017 WLAs for summer dry weather, winter dry weather and wet weather respectively.

(4) Addressing a variety of non-point sources discharges, including a variety of non-stormwater discharges to Avalon Bay, to assist in the achievement of the summer dry weather, winter dry weather and wet weather WLAs respectively.

(5) Addressing, as needed, legacy bacteria sources associated with groundwater.

The remainder of this Section 3 of the Compliance Plan describes the BMPs that the City will implement to address potential loading from each of these areas, as well as the monitoring that the City will perform to assess compliance with the WLAs.

B. Specific Load Reduction Strategies for POTW.

1. **Operational and Maintenance BMPs (POTW BMP 1).**

*Purpose* –To continue to operate and maintain the POTW in accordance with the requirements of the NPDES permit and industry standards to continue to achieve the "no exceedance" WLA for the POTW.

*Implementation Approach* – In accordance with its contract with the City, Environ Strategy must operate and maintain the POTW in accordance with the requirements of the NPDES permit and industry standards. As part of the contract, Environ Strategy must submit to the City an annual operations and maintenance plan to ensure proper operations and maintenance of the POTW. The annual operations and maintenance plan establishes the requirements for proper operations and maintenance of the POTW.

*Expected Benefits* –Proper operations and maintenance of the POTW will continue to allow the POTW to achieve the "no exceedance" WLA for the POTW.

C. Specific Load Reduction Strategies for the Collection System.

1. **Collection System Operations and Maintenance (Collection System BMP 1).**

*Purpose* – Collection system operations and maintenance efforts will identify and correct problems in the collection system in order to eliminate discharges.

*Implementation Approach* – In accordance with its contract with the City, Environ Strategy must establish and implement a Preventative maintenance program that meets the requirements of the City's Sewer System Management Plan ("SSMP"), State Board Order 2006-0003 and other applicable requirements. The preventative maintenance program includes, without limitation: a plan for regular monitoring and cleaning of the collection system and its lift stations; ongoing evaluation of a sewer maintenance list, including "hot spots"; closed circuit television video (CCTV) inspection; and a system to identify required rehabilitation.

*Expected Benefits* – Extended life of system and reduction in the excessive infiltration/inflow and system failures that can result in sanitary sewer overflows.

2. **Sanitary Sewer Overflow Reduction Plan (Collection System BMP 2).**

*Purpose* – The Sanitary Sewer Overflow Reduction Plan ("SSOR Plan") reviews existing maintenance activities and practices and makes recommendations for changes to sewer cleaning methods, tools and schedules to eliminate discharges of untreated or partially treated wastewater.

*Implementation Approach* –In June of 2012, RBF Consulting prepared a SSOR Plan for the City in accordance with the requirements of the CDO. The SSOR Plan reviewed the prior SSOs that had occurred in the sanitary sewer system, reviewed the current maintenance and operational procedures of Environ Strategy and made recommendations regarding the CCTV inspection program, manual operations, sewer cleaning, root treatment, pump station cleaning and inspection, private laterals and capital improvements. The City and Environ Strategy are currently implementing the recommendations of the SSOR Plan.

*Expected Benefits* – Reduction in sanitary sewer overflows.

3. **Sanitary Sewer Overflow Response Plan (Collection System BMP 3).**

*Purpose* – To establish procedures to respond to, contain, report and clean any overflows from the sanitary sewer system in order to protect public health and the environment.

*Implementation Approach* –The City and Environ Strategy have prepared a Sanitary Sewer Overflow Response Plan meeting the requirements of State Board Order 2006-0003, as embodied in the City's SSMP. The City and Environ Strategy will implement the Plan if an SSO occurs and will provide regular training to prepare for such events.

*Expected Benefits* – Contain and treat overflows before they result in discharges or impacts to public health and the environment.

4. **Computerized Maintenance Management System (Collection System BMP 4).**

*Purpose* – The Computerized Maintenance Management System ("CMMS") is used in conjunction with the City's Geographic Information System database to track and make accessible information concerning sewer line cleaning, overflows, system operation and maintenance data and other information necessary facilitate proper maintenance of the collection system and the POTW.

*Implementation Approach* – The City started using the CMMS in early 2012. Environ Strategy started populating the CMMS by collecting all of the equipment located at the wastewater treatment plant and throughout the sewer system. Any maintenance that occurs is recorded into the system.

*Expected Benefits* – Extended life of equipment and reduction in the amount of down time due to deferred maintenance.

5. **System-Wide Cleaning Program (Collection System BMP 5).**

*Purpose* – The System-Wide Cleaning Program proactively cleans all gravity sewers over four (4) years, identifies and remediates problems in gravity sewer segments, establish a condition-based proactive cleaning cycle and establishes inspection and cleaning schedules.

*Implementation Approach* – City has started a cleaning program that will clean 25% of the entire sewer collection system annually. City will also address hot spots on a more frequent basis.

*Expected Benefits* – Reduction in debris becoming stuck in lines and to remove roots that may cause a blockage in the sewer system.

6. **FOG Program (Collection System BMP 6).**

*Purpose* – FOG is known to be one of the leading causes of sanitary sewer overflows which occur when the sewer is clogged and the sewer discharges onto the street. Sanitary sewer overflows may cause temporary exceedances of applicable water quality objectives, pose a threat to the public health, adversely affect aquatic life and impair the public recreational use and aesthetic enjoyment of surface waters.

*Implementation Approach* – Through ordinance, the City will establish the legal authority to and will then implement a FOG program.

*Expected Benefits* – Elimination of any FOG related spills or reduction of man power that is required to treat hot spot areas.

7. **Private Lateral Repair Ordinance and Program (Collection System BMP 7).**

*Purpose* – The Private Lateral Repair Ordinance and Program will establish legal authority to identify private laterals which contribute to exceedances and facilitate repairs to those laterals.

*Implementation Approach* – A Private Lateral Repair Ordinance will be prepared and presented to the City Council for its consideration and recommended adoption. There will be two implementation plans, which will commence at the same time:

1 – All properties which are sold or which are renovated will be required to have a private lateral inspection and make required repairs as part of the condition of sale/improvement.

2 – The City will hire and train individuals to inspect private laterals using a 'zone' approach. Zone 1 will be all Bay Side Plumbing facilities (see more detail on this program below). Zone 2 will be the commercial business district. Zone 3 will consist of the residential neighborhoods of the City, divided into sub-zones. As each property is inspected a report will be maintained at the City and provided to the property owners. Each owner will be given a reasonable period of time to make necessary repairs. The City is exploring creating a loan fund to assist property owners who may have financial difficulties complying with repair costs.

*Expected Benefits* – The City believes that private laterals in need of repair are a significant contributor to exceedance issues. It is the City's belief that a private lateral program will reduce exceedances.

8. **Bay Side Plumbing Inspection Program (Collection System BMP 8).**

*Purpose* – There are facilities along the Bay that incorporate kitchen facilities, public restrooms or entertainment. Among these public and private are facilities owned and operated by the City. These facilities should be inspected on a regular basis.

*Implementation Approach* – The City will require an annual inspection of these facilities by the City's lateral inspection crew. Any necessary repairs will be required to be completed within 30 days of notice to the property owner.

*Expected Benefits* – The City believes these are among the most logical facilities which could contribute to Bay pollution. Eliminating plumbing leaks at these locations will provide an immediate benefit.

9. **Collection System Ordinance Update (Collection System BMP 9).**

*Purpose* – To ensure that the City has all legal authority necessary to prevent illicit connections to the collection system, to operate and maintain the system in good working order and to commence enforcement actions as appropriate.

*Implementation Approach* – The City Council will be presented with a sanitary sewer system ordinance for its consideration and recommended adoption.

*Expected Benefits* – Maintaining adequate legal authority

D. <u>Load Reduction Strategies for MS4</u>.

1. **Water Quality Ordinance (MS4 BMP 1).**

*Purpose* – To establish the legal authority necessary to effectively prohibit non-storm water discharges to the MS4 and to install controls to limit the discharge of pollutants from the MS4 to the maximum extent practicable.

*Implementation Approach* – A water quality ordinance will be developed and presented to the City Council for its consideration and recommended adoption.

*Expected Benefits* – The water quality ordinance will ensure that the City has the legal authority necessary to reduce pollutant, including FIB, loading from the MS4 to the Bay.

2. **Water Quality Management Plan (MS4 BMP 2).**

*Purpose* – To establish a comprehensive plan to effectively prohibit non-storm-water discharges to the MS4 and to install controls to limit the discharge of pollutants from the MS4 to the maximum extent practicable.

*Implementation Approach* – In conjunction with its anticipated enrollment under the State's Small MS4 permit, the City will develop and commence implementation of a water quality management plan.

*Expected Benefits* – The water quality management plan will assist the City in reducing pollutant, including FIB, loading from the MS4 to the Bay.

3. **Illicit Discharge, Detection and Elimination Program (MS4 BMP 3).**

*Purpose* – The illicit discharge, detection and elimination program provides additional tools for reducing and eliminating dry weather flows to the MS4.

*Implementation Approach* – As part of its existing permitting and code enforcement programs, and in conjunction with its Water Quality Management Plan, the City will implement an illicit discharge, detection and elimination program.

*Expected Benefits* – The program will reduce dry weather flows to the MS4, thereby helping to eliminate an FIB source.

4. **Low Impact Development/Infiltration Approaches (MS4 BMP 4).**

*Purpose* – To divert both dry weather and wet weather flows at the parcel level to areas that will permit infiltration rather than discharge to the MS4.

*Implementation Approach* – As part of its land use and planning functions, and in conjunction with its Water Quality Management Plan, the City will require the implementation of low impact development approaches on new construction and significant redevelopment projects. The City will also consider potential retrofit projects where feasible.

*Expected Benefits* – Onsite retention and infiltration will reduce both wet and dry weather discharges of pollutants from the MS4 to the Bay.

5. **Pet Waste Management and Control of Other Pathogen Sources (MS4 BMP 5).**

*Purpose* – To identify areas where there is a high volume and concentration of pet waste or other pathogen loading and to implement reduction strategies to reduce pet waste or other pathogen loading to the MS4.

*Implementation Approach* – The City will evaluate and expand as necessary programs to manage pet waste and other pathogen sources. As necessary, the City will consider adoption or expansion of its legal authority to control such sources. Including in this program would be an investigation and possible enforcement related to the Vista Del Mar Hotel.

*Expected Benefits* – Reduction of pet waste and other pathogen loading to the MS4 is expected to assist the City in reducing the FIB loading to the Bay.

6. **Continued Operation and Expansion of Low Flow Diverter Program (MS4 BMP 6).**

*Purpose* – To reduce and where feasible eliminate dry weather flows and "first flush" wet weather loading to the Bay.

*Implementation Approach* – The City will continue to operate and maintain the existing low flow diverters that divert dry weather flows and "first flush" wet weather loading from the Bay to the sanitary sewer system. The City will also consider causing or requiring the installation of low-flow diverters at drainage areas D2 and D5.

*Expected Benefits* – Continued operation and maintenance, and the possible expansion, of the low flow diverter program will assist in the reduction of FIB loading to the Bay.

E. Load Reduction Strategies for Non-Point Sources.

BMPs will be implemented to reduce controllable non-point sources of FIB, including the following:

1. **General Wash-Down Activities (Non-Point Source BMP 1).**

*Purpose* – Develop and implement controls for wash-down activities that result in discharges to the Bay.

*Implementation Approach* – The City will identify the times and locations of suspected wash-down activities in receiving waters and MS4 facilities. Once identified, the City will develop a program, which may include the adoption of ordinances to limit wash-down activities.

*Expected Benefits* – Elimination of wash-down activities that contribute to FIB eliminates a bacterial indicator source.

2. **Pier and Dock Cleaning BMPs (Non-Point Source BMP 2).**

*Purpose* – To eliminate pollution caused by waste which is washed directly from piers, floats and docks into the Bay. These locations are prime gathering spots for birds and thus resulting bird waste.

*Implementation Approach* – The City will explore alternatives to the current practice of simply hosing and brushing bird waste into the Bay. Initially, the City will acquire a set of machinery which scrubs and vacuums bird and other waste into tanks, which can then be disposed of at the waste water treatment plant. The City will also explore other treatment options, as feasible. The City will also work with private owners to implement similar cleaning techniques.

*Expected Benefits* – Recent moratoriums on dock washing have determined that not washing this material into the Bay resulted in a significant reduction bacterial loading to the Bay.

3. **Bird Control Efforts (Non-Point Source BMP 3).**

*Purpose* – To reduce the number of birds at or near the piers, floats, and docks and thereby reduce the amount of FIB loading to the Bay.

*Implementation Approach* – The City will continue to use a variety of strategies, including the use of a falconer, to reduce the presence of birds at key locations in the City. This includes, without limitation, the Green Pleasure Pier, where bird droppings are believed to be a major source of FIB loading. Including in this BMP will be the consideration of measures (such as enclosure of cubbyholes) under the Pleasure Pier that may reduce long-term bird populations at that location.

*Expected Benefits* – The reduction of the presence of birds at key locations in the City is expected to reduce the amount of FIB loading associated with bird droppings.

4. **Wrack Line Removal Program (Non-Point Source BMP 4).**

*Purpose* – To reduce FIB loading associated with regrowth of bacteria in the wrack line.

*Implementation Approach* – The City will consider continuation of its pilot program of daily removal of the wrack line from the beach and the shallow waters along the shore.

*Expected Benefits* – The daily removal of the wrack line is anticipated to reduce non-point source FIB loading to the Bay.

5. **Public Education Program (Non-Point Source BMP 5).**

*Purpose* – To educate the public about how human activities can create water quality problems at the Bay, and to hereby, over time, reduce anthropogenic FIB loading.

*Implementation Approach* – The City will implement an educational program designed to increase awareness of how human activities can create water quality problems in the Bay.

*Expected Benefits* – Public education is one of the best available strategies to reduce anthropogenic FIB loading to the Bay.

F. <u>Groundwater Load Reduction Strategies</u>.

1. **Legacy Bacteria Treatment (Groundwater BMP 1).**

*Purpose* – To continue monitoring and potentially treat highly localized "pockets" of groundwater contamination identified by sampling and testing of shallow groundwater wells.

*Implementation Approach* – The City will continue to test pockets of FIB contamination that have been identified in the subsurface, and work with the Regional Board to obtain approval, as needed, for the injection of dilute solutions of PAA into subsurface zones characterized by high contrentrations of FIB.

*Expected Benefits* – Evaluate the natural attenuation of FIB contaminated shallow groundwater, and accelerate FIB attenuation through the use of the disinfectant PAA as needed.

G. <u>Monitoring</u>.

In accordance with paragraph 30 of the CDO, the City will implement a water quality compliance monitoring program to determine compliance with the WLAs of the FIB TMDL. On a voluntary basis, and consistent with paragraph 36 of the CDO, which contemplates the possible establishment of a Santa Catalina Island-specific reference beach, the City may also perform enhanced monitoring, as described below, for data gathering and program development purposes.

1. **POTW Discharge Compliance Monitoring.**

To determine its compliance with the POTW WLA, the City will conduct compliance monitoring at receiving water monitoring location RSW-002 (described below), in accordance with the requirements of its existing NPDES permit for the POTW. The RSW-002 location correlates with the point of discharge from the POTW outfall and is the appropriate location to measure compliance with the POTW WLA. The Regional Board, in Order No. R4-2008-0028, NPDES No. CA0054372, established microbiological monitoring requirements for the POTW. These requirements consist of monthly sampling at four receiving water monitoring stations for total coliform, fecal coliform and enterococcus. The names and locations of the four monitoring stations required by the NPDES permit are as follows:

a. RSW-001 – Abalone Point, within 100 feet of the mean lower low water line.

b. RSW-002 – Outfall, at a point directly over the terminus of the ocean outfall.

c. RSW-004 – Pebbly Beach, at a point near the desalination plant infiltration well and within 50 feet of the mean lower low water line.

d. RSW-006 – Pebbly Beach, at a point approximately half way between RSW-001 and RSW-002 and within 200 feet of the mean lower low water line.

In accordance with its NPDES permit, the City will continue this receiving water monitoring at the four monitoring stations identified. However, because the TMDL is designed to measure compliance with the numeric targets at the point of discharge from the POTW, the City's compliance with the TMDL WLA will be measured using RSW-002. The City will continue to use the monitoring data from the other three locations as required by the NPDES permit. However, because these other three locations reflect water quality conditions that are not attributable only to the POTW discharge, they are not appropriate locations to measure the City's compliance with the POTW WLA.

2. **Avalon Bay Monitoring.**

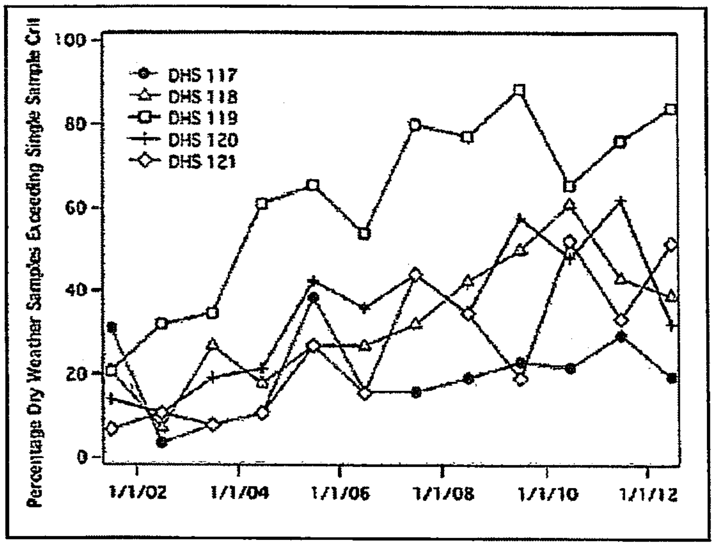
(a) <u>Water Quality Monitoring along the Avalon Bay Shoreline</u>

One of the requirements of the TMDL is that the City implement a water quality monitoring program to determine compliance with the WLAs related to the City's other facilities that discharge into the Bay. To help inform the City's development of its compliance monitoring plan for the Bay, the City undertook the two preliminary activities described below. First, it analyzed the results of prior Los Angeles Department of Health Services routine monitoring of Avalon Bay to ascertain historical water quality trends. Second, it conducted pilot testing of the City's expanded water quality monitoring program. This pilot testing allowed the City to verify its ability to conduct its own monitoring activities and also explored other possible monitoring locations that the City might, on a voluntary basis, wish to monitor. This Section 3.G.2.(a) of the Compliance Plan summarizes the results of these two activities. The next Section 3.G.2.(b) sets forth the City's specific FIB TMDL compliance monitoring plan as required by paragraph 30 of the CDO.

(i) *Historical Water Quality Trends*

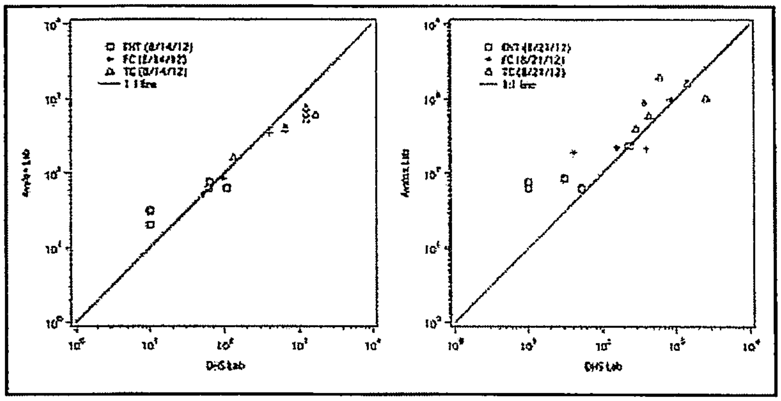
Beginning in the summer of 1999, the LA County Department of Health Services began collecting water samples from five sites in Avalon Bay. These sites are designated (from north to south) Tuna (DHS 121), Busy Bee (DHS 120), Middle (DHS 119), South (DHS 118), and Channel (DHS 117) (see map in Figure X below). Water samples are collected from each site once per week during the summer recreational period, from early April through the end of October. The sampling protocol is as follows. Typically, water samples are collected from each site on Tuesday morning (between 8:30 and 11:00 AM, depending on boat and helicopter schedules). Water samples are collected from ankle depth water on an incoming wave, placed on ice, flown back to the LA County Water Laboratory, and analyzed within 6 h using defined substrate tests Colilert-18 and Enterolert, implemented in a 96 well quantitray format. These tests yield the concentration of total coliform (TC), *Escherichia coli* (EC), and enterococci bacteria (ENT) in units of most probably number (MPN) per 100 mL of water sample. For comparison to the marine bathing water single-sample criteria, EC is assumed to be equivalent to fecal coliform (FC).

**Figure V.** *Trends in the percentage of water samples collected along the shoreline in Avalon Bay that exceeded one or more single-sample criteria for marine bathing water quality. The different curves correspond to the five sampling sites in Avalon Bay.*




To ascertain long-term trends in water quality at Avalon Beaches, the following analysis of Los Angeles Department of Health Service's routine monitoring data was carried out. For every summer monitoring period (early April through late October) the percentage of samples exceeding one or more of the single-sample criteria for ENT, EC, and TC was computed. Samples potentially impacted by rainfall were excluded from this analysis. A sample was considered impacted by rainfall if it was collected within three days of 0.1 inches or more of rain. The analysis was carried out for the eleven-year period beginning in the summer of 2001 (Figure V). Several trends are evident from these results:

**Figure W.** *Comparison of fecal indicator bacteria concentrations measured on split water samples collected from the shoreline in Avalon Bay by either the Avalon Laboratory (vertical axis) or the LA DHS laboratory (horizontal axis). The diagonal line represents a perfect 1:1 correspondence between the two labs.*

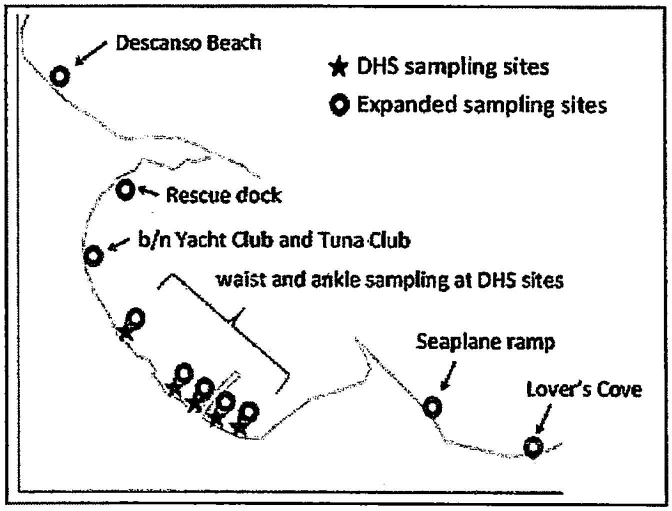


1. Over the eleven years, a highly variable percentage (between 4 and 88%) of water samples collected in Avalon Bay had FIB concentrations that exceeded one or more single-sample fecal indicator bacteria standards.
2. The percentage of water quality exceeding single-sample criteria exhibits distinct spatial trends:
   a. Samples collected from DHS 119 consistently had the highest percentage of single sample exceedences.
   b. Samples collected from DHS 117 consistently had the lowest percentage of single sample exceedences.
   c. All other three sites (DHS 118, 120, and 121) had an intermediate percentage of samples exceeding single sample criteria.
3. From 2001 through 2009 the percentage of samples exceeding single-sample criteria increased year-on-year. The rise was particularly dramatic at DHS 119, where the percentage of samples exceeding the single-sample criteria rose from 20% in 2001 to 88% in 2009.
4. After 2009, the percentage of samples exceeding single-sample criteria appeared to stabilize, and may be declining at some sites.

(ii) *City of Avalon's Expanded Avalon Bay Testing Program*

In support of the fieldwork planned for the summer of 2012, in late July a field laboratory was set up in a building located on the Avalon City Hall campus. The laboratory included, among other capabilities, the equipment and supplies necessary to collect and test water samples for ENT, EC, and TC using IDEXX Colilert-18 and Enterolert. As a first test of this facility, in early August the Los Angeles Department of Health Services began providing the City with splits of water samples they collected at Avalon Beach. Figure W compares, for two sampling dates, FIB concentrations measured by Los Angeles Department of Health Services (horizontal axis) and by the Avalon lab (vertical axis). FIB concentrations measured by the two labs are well within the natural variability typical of FIB measurements on coastal marine samples; i.e., a coefficient of variation of log-transformed concentrations of approximately 20%.

**Figure X.** *Existing LA DHS sampling sites (blue stars) in comparison to the proposed expanded sampling program, which includes water samples both within and outside of Avalon Bay.*




Over the summer of 2012, the City pilot tested an expanded beach monitoring program. The expanded program had the following three elements (Figure X):

(1) Ankle depth water at all of five DHS monitoring stations.

(2) Waist depth water at all five DHS monitoring stations.

(3) Additional sites within and outside of Avalon Bay. As of early October, these sites had been sampled between 6 and 7 times. These sites are:

- Descanso Beach: This beach site is located outside and approximately 1000 feet upcoast of Avalon Bay. The beach receives wet weather flows from a partially developed watershed which has relatively little in the way of MS4 and sanitary sewer infrastructure. This site represents a minimally urban-impacted reference site.

- Rescue Dock: This site is located within Avalon Bay, in a region of the Bay that has not been historically monitored for water quality, yet has a number of large installations (including the Fuel Dock, a restaurant, and the Casino Building) which could contribute bacterial pollution to the nearshore waters of Avalon Bay.

- o Between Yacht Club and Tuna Club: This site is located between the Yacht Club and the Tuna Club. This region of the Bay has not been historically monitored for water quality, but based on the SF6 study described in this Compliance Plan, the area may be impacted by sewage leaks from Bay Side Plumbing.

- o Seaplane Ramp: This site is located outside and approximately 300 feet downcoast of Avalon Bay. The beach receives wet weather flows from Pebbly Beach Road and the Mole facility, and has not been historically monitored for water quality.

- o Lovers Cove: This site is located outside and approximately 1000 feet downcoast of Avalon Bay. The site is a prime recreational diving location, and has not been historically monitored for water quality. It receives stormwater runoff from the hillside area and Pebbly Beach Road, and could be impacted by treated sewage discharged through the POTW outfall, in the unlikely event that the treated sewage plume surfaced and transport on shore.

The initial data from this expanded monitoring are presented in Figure Y. In this figure, the position of the red circles indicates sampling site locations, and the size of the circles denotes the percentage of samples exceeding one or more single-sample criteria. While very preliminary, these data are consistent with the following observations:

(1) DHS 119 has the highest percentage of samples exceeding one or more single-sample criteria.

(2) DHS 117 has the lowest percentage of samples exceeding one or more single-sample criteria.

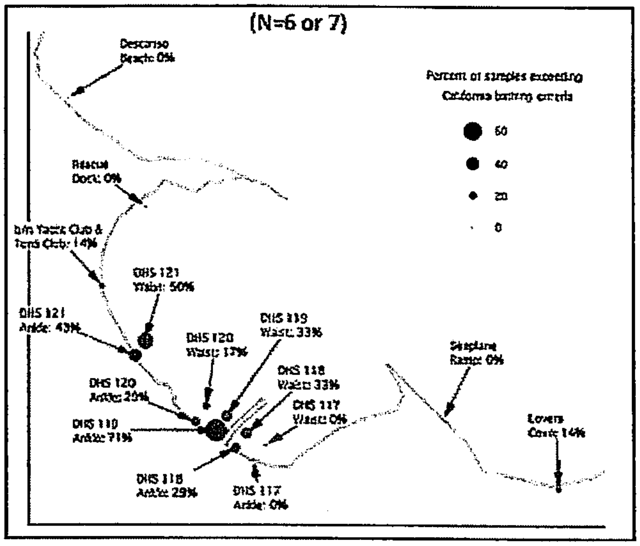
(3) At Los Angeles Department of Health Services sites, the collection of samples at ankle or waist depth did not dramatically affect the percentage of samples exceeding one or more single-sample standards.

(4) Water quality is generally poorest around the Pleasure Pier (DHS 118 and 119) and Step Beach (DHS 121).

(5) Water quality is better at other sampling sites in the Bay (between the Yacht Club and Tuna Club and at the rescue dock), as well as at sites located both northwest and southeast of the Bay (Descanso Beach, Seaplane Ramp, and Lovers Cove).

Points (1) and (2) are consistent with the analysis presented above regarding the historical monitoring data. The City is in the process of considering whether to continue its expanded monitoring program.

**Figure Y.** *Percent of samples collected as part of the Expanded Monitoring Program that exceed the State of California bathing water criteria (N-6 or 7).*




(b) Proposed TMDL Compliance Monitoring Plan

The FIB TMDL requires the City to monitor its compliance with the WLAs of the FIB TMDL at the 5 existing DHS monitoring stations, at the initial point of mixing with MS4 outfalls, and at one other designated monitoring station as set forth in paragraph 30 of the CDO (the Pebbly Beach site across from the pump station). As more fully described below, the City will measure its compliance with the WLAs of the FIB TMDL at these specific locations. The City's proposed monitoring plan for each of these locations is described in turn.

(1) <u>Existing DHS Monitoring Stations</u>: The City will conduct weekly monitoring at the existing set of Los Angeles Department of Health Services monitoring stations, as follows:

- DHS 117 Avalon Beach 100 feet east of the Green Pleasure Pier, Avalon
- DHS 118 Avalon Beach 50 feet east of the Green Pleasure Pier, Avalon
- DHS 119 Avalon Beach 50 feet west of the Green Pleasure Pier, Avalon
- DHS 120 Avalon Beach 100 feet west of the Green Pleasure Pier, Avalon
- DHS 121 Avalon Beach east of the Casino Arch at the steps, Avalon

(2) <u>Pebbly Beach Monitoring Station</u>: The City will conduct weekly monitoring at the Pebbly Beach site, across from the pump station, as required by paragraph 30 of the CDO.

(3) Monitoring at the initial point of mixing with MS4 outfalls (dry weather): There are seven MS4 outfalls (see Figure O above). One is the Bay outlet for the Clarissa Channel, another is a vault buried in the sand that drains the rooftop of the Vista Del Mar hotel (D5), and the rest are small sub-drainages in the downtown area (D1, D3, D4, D6, and D7) and at the Mole facility (D2). As noted in this Compliance Plan, most of these discharge points, including the Clarissa Channel, have low-flow interceptors. Because of the proper operation of these interceptors, runoff does not enter the Bay from the MS4 system during dry weather periods. Because there is no flow from these drains during dry weather, monitoring at the "initial point of mixing with MS4 outfalls" during dry weather periods is unnecessary, since there is no discharge at these points during dry weather. As part of its weekly monitoring, the City will conduct visual monitoring of the MS4 outfalls to verify that no discharges are occurring.

(4) Monitoring at the initial point of mixing with MS4 outfalls (wet weather): Stormwater runoff associated with rainfall events may exceed the capacity of low-flow interceptors, and under such circumstances, the excess runoff is discharged to the Bay. To comply with the TMDL requirement to monitor "at the initial point of mixing with MS4 outfalls", the following monitoring plan will be carried out when there is wet weather during the City's regular weekly monitoring of the DHS and Pebbly Beach sites:

- Drainages D1, D3, and Clarissa Channel: These MS4 outlets are within 100 feet of the existing DHS 117 site. Therefore, the wet weather impacts of these outlets on Bay water quality will be monitored during the collection of the regular weekly water samples from DHS 117.

- Drainage D2: This MS4 outlet is located near Gate 3 at the Mole. There are no existing DHS monitoring stations at this location. Therefore, during wet weather events that occur during the City's regular weekly monitoring at the DHS and Pebbly Beach sites, an additional wet weather monitoring site will be established at the point where runoff from Drain D2 mixes into Avalon Bay.

- Drainages D4, D5, and D6: These MS4 outlets are located within 50 feet of the existing DHS 119 and DHS 120 sites. Therefore, the wet weather impacts of these outlets on Bay water quality will be monitored during the collection of the regular weekly water samples from DHS 119 and 120.

- Drainage D7 : This MS4 outlet is located within 50 feet of the existing DHS 121 site. Therefore, the wet weather impacts of these outlets on Bay water quality will be monitored during the collection of the regular weekly water samples from DHS 121.

(c) Monitoring Schedule.

Monitoring will be conducted year round on a nominal weekly schedule. In the event the concentration of FIB in a water sample exceeds one or more single-sample criteria at a compliance monitoring location, the City will adopt the same procedure used by the Los Angeles

Department of Health Services. Namely, the site will be re-sampled within three days after the original sample was collected.

(d) Proposed Sampling Procedure and Analysis.

Samples will be taken at ankle depth on an incoming wave. Where there is a freshwater outlet, during wet weather, samples will be taken as close as possible to the initial point of mixing with the receiving water, but not further than 10 meters down current of the sampling point. Water samples will be collected with sample containers containing sodium thiosulfate (to deactivate any residual disinfectants that may be present in the water sample), immediately placed on ice, and transported to the Avalon laboratory for processing within 3 hours of collection. Water samples will be analyzed for the FIB total coliform (TC), *E. coli* (EC), and enterococci bacteria (ENT) using IDEXX Colilert-18 and Enterolert, following manufacturers recommendations. All samples will be conducted, preserved and analyzed according to the procedures under 40 CFR part 136.

## SECTION 4. COMPLIANCE SCHEDULE AND PROPOSED MILESTONES

A. Compliance Schedule.

The CDO establishes deadlines for achieving the City's WLAs. Implementation of the Compliance Schedule as described below is intended to meet these deadlines. Table 1 summarizes the schedule for the implementation methods identified in the Compliance Plan.

**Table 1. Compliance Schedule**

| BMP | Description | Completion Date |
|---|---|---|
| POTW BMP 1 | Continue to operate and maintain the POTW in accordance with the requirements of the NPDES permit and industry standard | Ongoing |
| Collection System BMP1 | Implement the Preventative Maintenance Program | Ongoing |
| Collection System BMP 2 | Develop Sanitary Sewer Overflow Reduction Plan and implement its recommendations | The SSO Reduction Plan was completed in June of 2012. Implementation is ongoing. |
| Collection System BMP 3 | Update the Sanitary Sewer Overflow Response Plan and implement its requirements | The SSO Response Plan was updated in June of 2012 as part of updates to the City's SSMP. Implementation is ongoing. |
| Collection System BMP 4 | Implementation of a Computerized Maintenance Management System | The CMMS was implemented by the City in early 2012 and its use is ongoing. |
| Collection System BMP 5 | Implementation of a system-wide cleaning program | Implementation of the program has commenced and the City will clean 25% of its collection system annually. |
| Collection System BMP 6 | Development and implementation of a FOG program | June 30, 2013. |
| Collection System BMP 7 | Development of a private lateral repair ordinance and program | December 31, 2013. |
| Collection System BMP 8 | Bay Side Plumbing inspection program | Commence program by January 31, 2013; complete initial inspections by June 30, |

| BMP | Description | Completion Date |
|---|---|---|
| | | 2012; ongoing thereafter. |
| Collection System BMP 9 | Amendments to the City's sewer ordinance | June 30, 2013. |
| MS4 BMP 1 | Development of a water quality ordinance | June 30, 2013. |
| MS4 BMP 2 | Development of a water quality management plan | December 31, 2013. |
| MS4 BMP 3 | Implementation of an MS4 illicit discharge, detection and elimination program | December 31, 2013. |
| MS4 BMP 4 | Implementation of low impact development/infiltration requirements | December 31, 2013. |
| MS4 BMP 5 | Pet waste management and control of other pathogen sources | June 30, 2013. |
| MS4 BMP 6 | Continued operation and expansion of low flow diverter program | Ongoing. |
| Non-Point Source BMP 1 | Develop and implement controls for wash-down of boats, piers and floats | March 31, 2013. |
| Non-Point Source BMP 2 | Pier and dock cleaning BMPs | March 31, 2013. |
| Non-Point Source BMP 3 | Continue bird control efforts | Ongoing. |
| Non-Point Source BMP 4 | Wrack Line Cleaning | Commence program by March 31, 2013; ongoing thereafter. |
| Non-Point Source BMP 5 | Public Education | June 30, 2013. |
| Groundwater BMP 1 | Injection of dilute solutions of PAA into subsurface zones characterized by high concentrations of FIB. | As needed, based on the results of the additional groundwater testing. |

B. Proposed Milestones for Achievement of the WLAs.

1. **Milestones for the achievement of the POTW WLA**

The POTW WLA is already in effect and there are to be "no exceedances" of the FIB numeric targets from the POTW. To date, the City's monitoring indicates that the City is in compliance with the WLA. Through the implementation of POTW BMP 1, the City believes that it will remain in a position to continue to achieve this WLA.

2. **Milestones for the achievement of the June 30, 2015 Collection System WLA**

The WLA for the collection system requires that by June 30, 2015, there be no discharges from the collection system that result in detectable levels of the fecal indicator bacteria identified as numeric targets in the TMDL. In simple terms, this means that the City's collection system (i.e., the public wastewater collection system it owns and operates) must not discharge detectable levels of FIB by June 30, 2015. Because of the collection system upgrade the City completed in the summer of 2012, the City believes that it has remedied the problems associated with the its collection system. Through Collection System BMPs 1-6 and 9, the City believes that it will remain in a position to achieve the WLA from the collection system. As identified in this Compliance Plan, the City needs to address the Bay Side Plumbing in particular and private laterals in general to remedy potential leaks from those facilities. Through Collection System BMPs 7 and 8, the City will, by June 30, 2013, have programs in place to address these sources. Therefore, as milestones to achieve the WLA, the City will seek to achieve the following reductions:

- By June 30, 2014, it would reduce any discharges associated with the sewer collection system by 50%.
- By June 30, 2015, it would achieve the "no exceedance" WLA.

The City will measure its achievement of these milestones through additional $SF_6$ or similar testing that is designed to assess the integrity of the collection system.

3. **Milestones for the achievement of the April 1, 2016 Summer Dry Weather WLA**

The WLA for summer dry weather provides that there be no allowable exceedances during summer dry weather (April 1 to October 31) by April 1, 2016. To achieve this WLA, the City will implement MS4 BMPs 1-6 and Non-Point Source BMPs 1-5 on or before December 31, 2013. Certain key BMPs, such as Non-Point Source BMPs 1-4, which the science suggests should result in direct improvements to water quality, will be implemented by March 31, 2013, before the next summer dry weather season. Collectively, and over time, the City believes that these BMPs will put it in the best position to achieve the WLA. As milestones, the City will seek to achieve the following reductions:

- A 33% reduction of exceedances from 2012 levels during the 2013 summer dry weather season.

- An additional 33% reduction of exceedances from 2012 levels during the 2014 summer dry weather season.

- An additional 33% reduction of exceedances from 2012 levels during the 2015 summer season.

Through an adaptive management process, the City will need to adjust these milestones and its BMPs based upon the monitoring data. It is possible that the City, despite implementation of its BMPs, may not achieve these milestones. If that occurs, the City will need to adaptively manage its program and try to develop new or additional BMPs. Given the difficult nature of FIB, the no exceedance requirement will be a difficult one to reach, but the City believes that the implementation of the BMPs identified in the Compliance Plan will best place it in a position to achieve the requirements of the WLA.

**4. Milestones for the achievement of the November 1, 2016 Winter Dry Weather WLA**

The WLA for winter (November 1 to March 31) dry weather, based upon the City's proposed weekly monitoring plan, is 1 allowable exceedance day per season starting November 1, 2016. To achieve this WLA, the City will implement MS4 BMPs 1-6 and Non-Point Source BMPs 1-5 on or before December 31, 2013. To measure it progress toward the achievement of this WLA, the City will first establish a winter dry weather "baseline" using its monitoring from the November 1, 2012 to March 31, 2013 season. From this baseline, the City would establish as milestones an annual 33% exceedance reduction goal. Therefore, the City would seek to achieve the following reductions:

- A 33% reduction from the winter dry weather "baseline" by March 31, 2014.

- An additional 33% reduction from the winter dry weather "baseline" by March 31, 2015.

- An additional 33% reduction from the winter dry weather "baseline" by March 31, 2016.

Through an adaptive management process, the City will need to adjust these milestones and its BMPs based upon the monitoring data. It is possible that the City, despite implementation of its BMPs, may not achieve these milestones. If that occurs, the City will need to adaptively manage its program and try to develop new or additional BMPs.

**5. Milestones for the achievement of the November 1, 2017 Wet-Weather WLA**

The wet-weather WLA is, again assuming a weekly monitoring schedule, 3 allowable exceedances and geometric mean targets by November 1, 2017. To achieve this WLA, the City will implement MS4 BMPs 1-6 and Non-Point Source BMPs 1-5. Because the City lacks a firm wet-weather baseline, the City would use data from the November 1, 2012 to October 31, 2013 period to establish a wet-weather baseline. The City would then establish, as milestones, an annual 25% reduction in exceedances from this baseline. Therefore, the City would seek to achieve the following reductions:

- o A 25% reduction from the wet weather "baseline" by October 31, 2014.
- o An additional 25% reduction from the wet weather "baseline" by October 31, 2015.
- o An additional 25% reduction from the wet weather "baseline" by October 31, 2016.
- o An additional 25% reduction from the wet weather "baseline" by October 31, 2017.

Through an adaptive management process, the City will need to adjust these milestones and its BMPs based upon the monitoring data. It is possible that the City, despite implementation of its BMPs, may not achieve these milestones. If that occurs, the City will need to adaptively manage its program and try to develop new or additional BMPs.

## SECTION 5. CONCLUSION

The City submits this Compliance Plan in accordance with paragraph 28 of the CDO. The Compliance Plan provides a detailed description of Avalon Bay, the potential sources of FIB loading to the Bay and a compliance schedule, with proposed milestones, to achieve the WLAs of the FIB TMDL. The City has made great progress, through, among other things, its recently completed sewer collection system upgrade, to reduce FIB loading to Avalon Bay. Through this Compliance Plan, the City has set forth a path for achieving the requirements of the FIB TMDL.